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SONAR TRANSDUCER RELIABILITY IMPROVEMENT PROGRAM (STRIP) FY81.(U)
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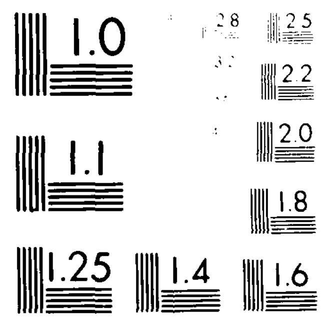
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The Sonar Transducer Reliability Improvement Program (STRIP) is sponsored by Naval Sea Systems Command (SEA63X5)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Transducers	Connectors	Environmental tests	Shielding
Corona	Noise & vibration	Plastics	Rubbers
Transducer fluids	Pressure release	O-Rings	
Encapsulation	Material evaluation	Ceramics	
Cables	Water permeation	Metal matrix composites	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During the fourth quarter of FY81, efforts in the various tasks of STRIP have resulted in progress toward the program goals as summarized below:

- Four coating materials have shown the ability to increase the electrical lifetime of PZT ceramic. A strong recommendation was made that Humiseal 2A53 be used for an insulating coating material on the PZT ceramic in the AN/SQS-56 transducer instead of the Conap EN-2 used previously. (continued)

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Long-term water permeation experiments give initial indications that sodium chloride is not carried through the transducer elastomer. The composition of the elastomer is not significantly affected. DI water does not reach a steady state equilibrium permeation rate. However, it has been shown that drastic electronic changes in transducers caused by high temperature, humid aging can be nearly completely nullified by a thorough drying.

An improved transducer has been developed and demonstrated as superior to the TR-122 (BQC-1). All performance specifications, before and after explosive shock, have been met.

Recommendations are made for improving the reliability and performance of the DT-276 hydrophone.

CONTENTS

SONAR TRANSDUCER RELIABILITY IMPROVEMENT PROGRAM

FY81 FOURTH QUARTER PROGRESS REPORT

1. INTRODUCTION

1.1. PROGRAM OVERVIEW

The general objective of this program is to perform relevant engineering development which addresses the operational requirements for fleet transducers for active sonar, passive sonar, surveillance, counter-measures and deception devices, navigation, and acoustic communications. The approach is to develop, test, and evaluate improved transducer design, materials, components, and piece-parts that will meet specified requirements in the operational environment during the entire useful life of the transducer. Standards will be prepared to ensure that results obtained during preliminary testing will be obtained consistently in production. This program should result in improved performance and reliability and reduced costs through better utilization and a more comprehensive characterization of materials and design data.

The Sonar Transducer Reliability Improvement Program (STRIP) is a part of Program Element 64503N. Major task areas with specific objectives to achieve the program goals have been described in the Program Plan and include:

- Task Area A - Encapsulation Methods
- Task Area B - High-Voltage Engineering
- Task Area C - Cables and Connectors
- Task Area D - Transducer Material Standards
- Task Area E - Environmental Test Methods
- Task Area F - Transducer Tests and Evaluation

The FY81 Program Plan for STRIP has been funded at the $1017K level. The specific tasks and their principal investigators for FY81 are:

TASKS		PRINCIPAL INVESTIGATORS	
A	Encapsulation Methods	NRL-USRD	C.M. Thompson
B	High-Voltage Engineering	NRL-USRD	L.P. Browder
C-1	Cables & Connectors	EB/GD	R.F. Haworth
C-2	Cable Shielding	Georgia Tech	H.W. Denny

C-3	Standard for O-Ring Installation	APL/University of Washington	C.J. Sandwith
D-1	Alternative Materials: Plastics	NWSC	K. Niemiller
D-2	Pressure Release Materials	NUSC	C.L. LeBlanc
D-3	Specification of Elastomers	NRL-USRD	C.M. Thompson
D-4	Transducer Ceramics	NRL-USRD	A.C. Tims
E-1	CUALT	NOSC	J. Wong
E-2	ALT Verification	NWSC	D.J. Steele
F-1	Failure Modes due to Water	TRI	P.E. Cassidy
F-2	Ceramic Stack Joints	NOSC	C.I. Bohman
F-3	Reliability & Life Prediction Specifications	TRI	R.L. Smith
F-4	TR-122 FMA & Improvements	NRL-USRD	E.W. Thomas
F-5	Metal Matrix Composites	Honeywell	O.L. Akervold
F-6	Improved Hydrophone Analysis	NWSC	J.A. Parkes
F-7	Engineering Documentation	NRL-USRD	R.W. Timme

1.2. SUMMARY OF PROGRESS

During the fourth quarter of FY81, efforts in the various tasks of STRIP have resulted in progress toward the program goals as summarized below:

- Four coating materials have shown the ability to increase the electrical lifetime of PZT ceramic. A strong recommendation is made that Humiseal 2A53 be used for an insulating coating material on the PZT ceramic in the AN/SQS-56 transducer instead of the Conap EN-2 used previously. See Section 3.

- Long-term water permeation experiments give initial indications that sodium chloride is not carried through the transducer elastomer. The composition of the elastomer is not significantly affected. DI water does not reach a steady state equilibrium permeation rate. However, it has been shown that drastic electronic changes in transducers caused by high temperature, humid aging can be nearly completely nullified by a thorough drying. See Section 11.

- An improved transducer has been developed and demonstrated as superior to the TR-122 (BQC-1). All performance specifications, before and after explosive shock, have been met. See Section 14.

- Recommendations are made for improving the reliability and performance of the DT-276 hydrophone. See Section 16.

- The FY82 Program Plan is presented in Appendix A.

The following reports were issued during FY81:

- L.P. Browder, "Estimation of electrical reliability of underwater sound transducers," submitted to IEEE for publication.

- R.L. Smith, "Reliability and Service Life Concepts for Sonar Transducer Applications," NRL Memorandum Report 4558.

- P.E. Cassidy, "Failures Due to Water Permeation into Transducers," TRI Technical Report 7973 (Nov 1980).

- J.S. Thornton, "Sonar Transducer Reliability Program," TRI Technical Report 8185 (Jul 1981).

- C.M. Thompson, "Permeation into containers filled with nonideal oil," J. Appl Polymer Science <u>26</u>, [illegible]3-377 (1981).

- C.M. Thompson, "Permeation into Transducers," TR-155F Workship presentation (Jan 1981).

- C.M. Thompson, "Permeation Through Elastomers," Sonar Rubber Dome Window presentation (sep 1981).

- R. Haworth, "Handbook of Pressure-Proof Connector and Cable Harness Design for Sonar Systems," NRL Memorandum Report 4601.

- D.E. Glowe and [illegible] Arnett, "The Application of Mechanical Clamps to Portsmouth Connectors," NRL Memorandum Report [illegible]62.

- "DT-27[illegible] Hydrophone Study," TRACOR Applied Science Technical Report N00197-80-C-0223 (Jul 1981).

- L.P. Browder, "[illegible]/SQS-56 Transducer Corona," NRL Ltr Report to NOSC (26 Mar 1981).

- C.M. Thompson, "Development of Encapsulants for Sonar Transducers," published as the Statement of Work in RFP [illegible]14-81-R-MA20, <u>Commerce Business Daily</u>, [illegible] May 1981).

- A.C. Tims, "Effects of multidimensional stress on radially polarized peizoelectric ceramic tubes," JASA <u>70</u>, 21-28 (1981).

- C.J. Sandwith, "Handbook for O-Ring Installation for Underwater Components and Applications," to be published as an NRL Memorandum Report.

- P.E. Cassidy, G.C. Rolls, and Shawn Arnett, "Effect of internal humidity on a sonar transducer," ASA Conference, Miami Beach, FL (Dec 1981).

- C.I. Bohman and G.L. Goodhart, "Performance Degradation Related to Elevated Temperatures in a Stacked Ceramic Ring Longitudinal Resonator," NOSC Technical Report.

- R.L. Smith, "Incorporating dispersion measures into exponential reliability modeling descriptions," submitted to Naval Research Logistics Quarterly for publication.

- R.W. Timme, "Sonar Transducer Reliability Improvement Program FY81 First Quarter Progress," NRL Memorandum Report 4418.

- R.W. Timme, "Sonar Transducer Reliability Improvement Program FY81 Second Quarter Progress," NRL Memorandum Report 4487.

- R.W. Timme, "Sonar Transducer Reliability Improvement Program FY81 Third Quarter Progress," NRL Memorandum Report 4543.

- R.W. Timme, "Sonar Transducer Reliability Improvement Program FY81 Fourth Quarter Progress, NRL Memorandum Report 4615.

1.3. PLANS

The FY82 program is described in Section 17 of this report and will be implemented as soon as funds can be distributed.

1.4. REPORT ORGANIZATION

The remaining sections of this quarterly report will discuss the objectives, progress, and plans for the specific tasks included in the STRIP.

2. TASK A - ENCAPSULATION METHODS

[illegible]

2.1. BACKGROUND

A material to be used for filling a sonar transducer must meet a wide variety of specifications. The requirements imposed by the electrical nature of the device include high resistivity, high dielectric constant, as well as resistance to corona and arc discharges. The water environment of the transducer necessitates low water solubility and other attractive solution properties. In addition, the fluid must maintain its electrical and other properties in the presence of any water which permeates the covering. The acoustic requirements are a close acoustic impedance match with seawater and resistance to cavitation at high drive levels. Other obvious properties include compatibility with other components, stability to degradation, and suitable surface tension and viscosity.

With such a wide variety of requirements, it is not surprising that compromises have to be made. The most commonly used fluid for many years has been castor oil. This use in is spite of its high viscosity. Each of the fluids proposed, so far, as a replacement has serious drawbacks. This greatly complicates bonding the components together. Polyalkylene glycol (PAG) has the disadvantages of high water solubility and low electrical resistivity. The various hydrocarbon liquids have too low an acoustic impedance and are frequently incompatible with the various plastics and rubbers in the transducer. Further research is necessary to find and qualify fill-fluids which represent the best match to all the requirements imposed upon it.

Transducer encapsulants have long presented a source of transducer failure. The necessity that the encapsulants be resistant to water, have a sufficiently long pot-life for degassing, bond well to the other components, and have high strength has proved to present a very difficult problem. Many other requirements also apply in special cases. The best choice for a polyurethane encapsulant to date has been a toluene diisocyanate (TDI)-polytetramethylene glycol (PTMG) prepolymer which is chain extended with a 4,4'-methylene-bisorthochloroaniline (MOCA). This encapsulant has a long pot-life, good strength, and good water resistance. However, there is serious concern for the health hazards of both the MOCA and the TDI residue in the prepolymers.

2.2. OBJECTIVES

The objectives of this task are:

- To evaluate alternative transducer fill-fluids including fluids specifically for use in towed arrays and to produce specifications for those fluids found suitable.

- To define the relevant properties of encapsulants important in transducer operation, and to develop a non-hazardous replacement for currently used materials.

2.3. PROGRESS

2.3.1. In response to NRL's solicitation for a non-proprietary polyurethane encapsulant, nine proposals were received. The Source Selection and Evaluation Board met and a contract was finally awarded late this quarter to the Products Research and Chemicals Corporation for the development of a non-proprietary polyurethane transducer encapsulant. Because of the delays in awarding this contract, no work was possible during FY81. The work to be performed during the course of the contract includes the preparation of polyurethane samples based on:

- Methylene bis(phenyl isocyanate) (MDI), poly MDI, isophorone diisocyanate, and methylene bis(cyclohexyl isocyanate).

- Hydroxyl-terminated polybutadiene (PBD), with various alkyl diols, and PBD copolymerized with polyethers.

- Several relatively new curing agents which are non-hazardous.

Other synthesis considerations such as reaction conditions and catalysts will also be examined.

The materials prepared will be evaluated according to a ranked order of tests, including tensile strength and modulus, water permeation, pot-life and viscosity, bondability, acoustic impedance, Shore A hardness, volume electrical resistivity, glass transition temperature and acoustic attenuation. Environmental tests will also be performed in order to minimize the degradation of the polyurethane compound in water. The end product of the research will be a formula specification of acoustic polyurethane encapsulants. This formula specification should lead readily to a design specification for transducer encapsulants.

2.3.1. In the FY81 Third Quarter STRIP Progress Report[1] the properties of butvl-capped and methyl-capped PAG derivatives were presented. The density and sound speed of these modified fluids are surprisingly lower than those of water. Several attempts have therefore been made under the NRL 6.1-funded research program to produce fluorinated alkyl-capped polyether transducer fluids. These compounds should, by analogy, have excellent acoustic properties in addition to adequate compatibility and environmental properties. Unfortunately, synthesis difficulties have been encountered in that the electron-withdrawing nature of the fluorine substituent and the different solubilities of the reactants have been found to drastically alter the reaction conditions. Future attempts will involve reverse ether synthesis and use of a phase transfer catalyst.

2.3.3. PLANS

- Polyurethane encapsulant synthesis and evaluation under the awarded contract.

- Perforr testing or modified polyethers as they are produce

3. TASK B-1 - CORONA ABATEMENT

L.P. Browder - NRL-USRD

3.1. BACKGROUND

A significant percentage of transducer failures is due to voltage breakdown of insulating materials developing from corona erosion mechanisms. It is not practical to test the completed transducer to measure the effects of corona erosion on lifetime and reliability. To establish reliability factors and quantify protection requirements, corona must be studied as a failure mechanism at the component or piece-part level. Transducer reliability improvement may then be achieved by control of design parameters and construction processes.

3.2. OBJECTIVES

The objectives of this task for FY81 are:

- Study tests, specifications, and procedures that may be used to select coating materials suitable for corona reduction.

- Test various corona reduction coating materials on PZT ceramic to identify the voltage breakdown mechanisms and measure voltage lifetime functions with the coating materials that show improvement.

3.3. PROGRESS

3.3.1. Tests were performed to measure the voltage endurance function for the surface of PZT ceramic covered with insulating conformal coating materials. The test is the same one used to measure the voltage endurance function of PZT ceramic in various insulator gases.[2] The result of these measurements describes the dependence of dielectric strength on the time of exposure to high voltage. The failure event is specifically indicated by electrical arcing between the test specimen electrodes.

Four of the coating materials from the group chosen for evaluation were selected for the voltage endurance testing. The manufacturers and material types were:

- Humiseal Division, Columbia Technical Corporation
  Types 1A27 and 2A53

- Conap, Inc.
  Types CE-1132 and CE-1170

One of the main criteria for selection of these materials is the ability of the coating to increase the corona inception voltage (CIV) of the test specimens. The average improvement observed for the four chosen materials had a range of 5 to 15%, while those not tested had a range from no improvement to -20%.

The manufacturer's description for each of the four chosen materials follows:

- Humiseal 1A27 - one-component polyurethane
- Humiseal 2A53 - two-component modified epoxy
- Conap CE-1132 - one-component synthetic polymer
- Conap CE-1170 - one-component acrylic

In addition, the 2A53 and CE-1170 materials meet the requirements of MIL-I-46058C. The other two materials are not stated to meet any MIL specification. All of the materials are easy to work with.

Figure 3.1 shows the data obtained from the voltage endurance tests made on the coated PZT specimens. The vertical scale of this graph is expanded for ease of data presentation. In the process of the tests, it became obvious that there is no essential difference between the voltage endurance functions described by the four materials. Any differences obtained from further averaging of the data can only be of minor significance.

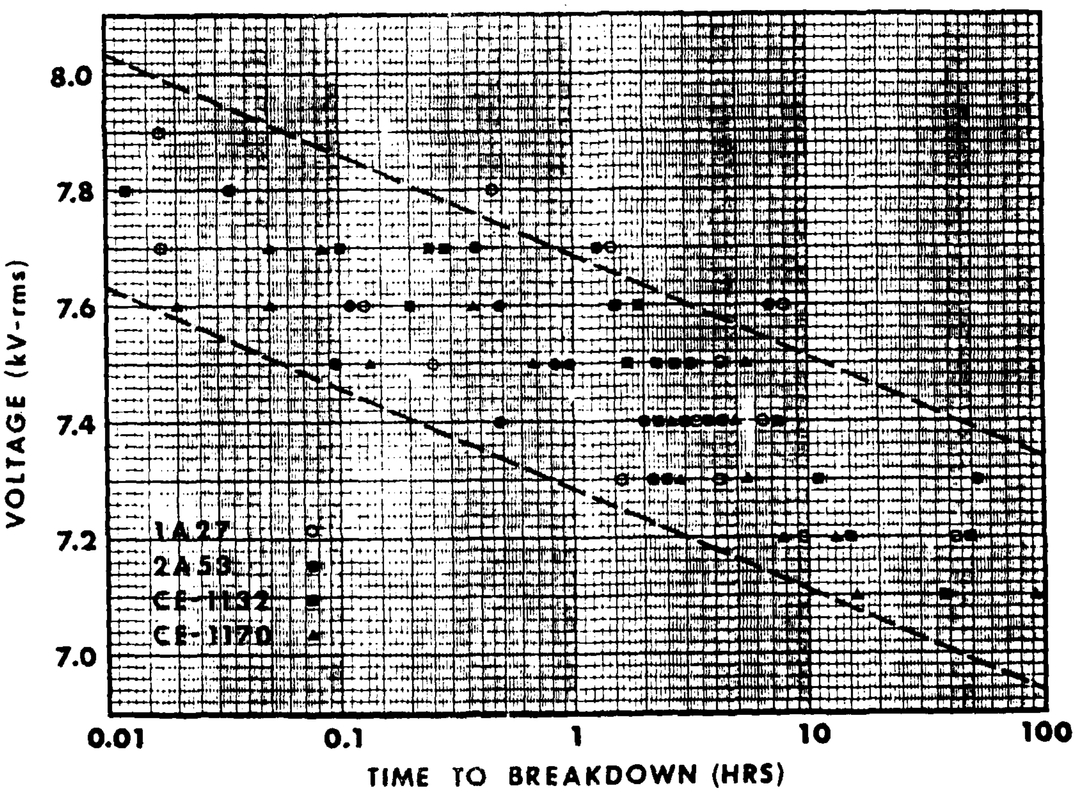


Fig. 3.1 - Voltage endurance data for 0.635-cm thickness PZT ceramic treated with insulating conformal coatings.

- The vapors produced by these coating materials in the mixing or curing operation may be irritating to some people and therefore require special ventilation in the working area.

It is concluded that any of these four coating materials is an adequate protection device to suppress electrical breakdown on the surface of PZT ceramic. The actual choice of a particular material depends on the handling properties needed for the manufacturing process.

3.3.2. Some tests were performed in an attempt to measure the voltage endurance function for PZT specimens treated with trifunctional silane. The results were generally inconclusive due to a relatively wide scatter of the breakdown voltage for the test specimens. About half of the specimens failed early at voltages in the range 6.5 to 7.5 kV. The tests that were successfully run for a significant time period (0.5 to 10 hours) operated in a range near 7.1 kV. The remaining tests for this series were canceled when it became apparent that this silane treatment would yield only a small improvement, if any, over untreated PZT ceramic.

An observation concerning voltage breakdown on these specimens is that arcing nearly always burns a deep white channel in the surface of the PZT. This could mean that the silane treatment reduces the resistance of the PZT surface to electrical degradation due to arcing. This type breakdown is sometimes observed on untreated PZT, but generally arcover produces a shallow dark line.

Two other variations of the silane treatment were tested for CIV and breakdown voltage values. These tests yielded no results considered promising enough to continue the investigation. It is therefore not expected that any emphasis on silane treatment of PZT ceramic will be considered in the future.

3.3.3. Four more coating materials were given preliminary evaluation for use in this application. These are the Conap types CE-1171, EN-2, EN-7, and EN-12. They were overlooked when the original choice of materials for test were made. Type EN-2 is of special interest because it is used in the current production of AN/SQS-56 transducers.

The preliminary evaluation of CE-1171 indicates it to be one of the best materials tested so far. The CIV measurements showed an increase of 18% and a small but consistent increase of short-time breakdown voltage. It also had very good adherence to the PZT surface. This material will be given further voltage endurance tests.

The EN-2 polyurethane resin potting material showed an average change of -20% for the CIV measurements. The short-time breakdown voltage was about average and the material adheres poorly to the PZT surface.

Material types EN-7 and EN-12 had CIV measurement changes of -5% and +9% respectively. Breakdown voltage was average and there was fair to poor adherence. The viscosity of the uncured material for both types was high and it is a necessity to vacuum degas it before use.

The shaded area in Fig. 3.2 encloses the data area of Fig. 3.1, which is shown in relation to voltage endurance functions obtained for uncoated PZT specimens in dry air and sulfur hexafluoride (SF_6) gas.[2] The graph shows that these surface coatings are approximately as effective as SF_6 gas fill for improving the electrical reliability of transducers.

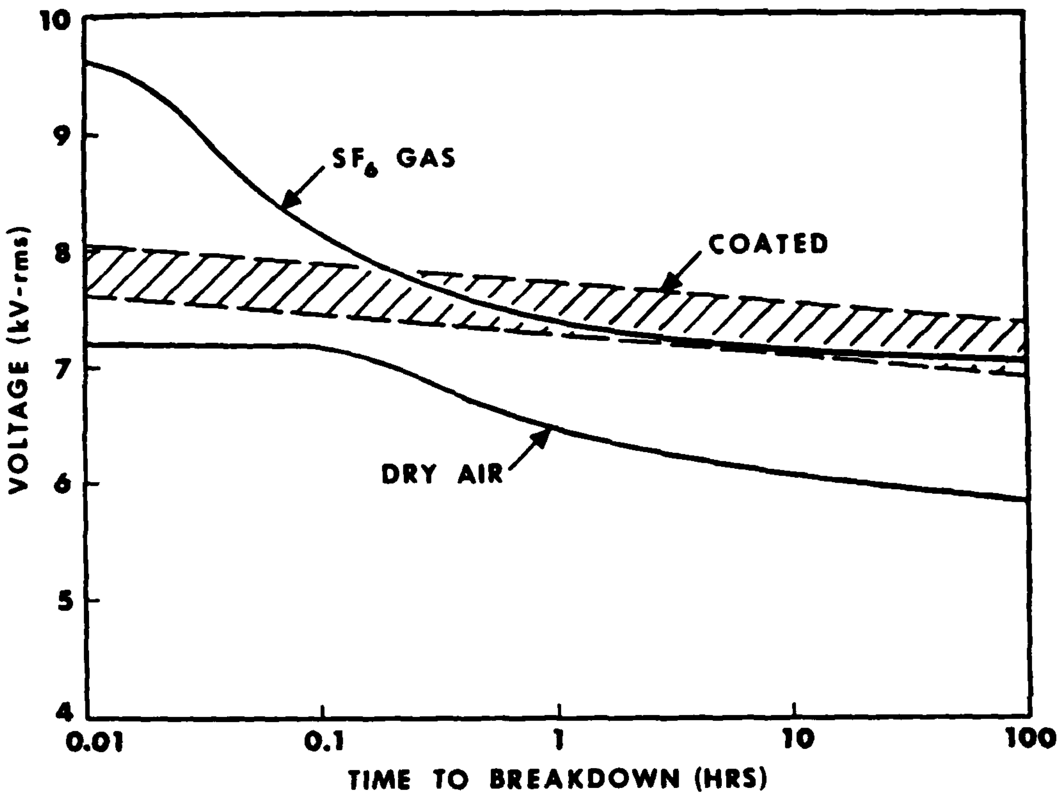


Fig. 3.2 - Comparison of voltage endurance functions for PZT ceramic coated or untreated in two different insulator gases.

Other observations made concerning these coating materials include:

- Electrical breakdown occurred in the air path outside the coating. There was no evidence of breakdown between the PZT surface and coating.

- There was no cracking or crazing of the coating material. All seem to be adequately flexible.

- There was no evidence of separation between the PZT surface and coating caused by the tests. Adherence of the coating materials was sufficient.

- The coating materials are more resistant than the PZT surface to electrical degradation caused by arcing.

3.3.4. It is recommended that the Humiseal coating material type 2A53 be given serious consideration for use in place of the Conap material type EN-2 that is mentioned in section 3.3.1.5.1 of the AN/SQS-56 Sonar Specification. This recommendation is based on the following factors:

- The cured physical properties of the two materials are very similar and should be comparable in any manufacturing process.
- The 2A53 material has demonstrated its ability to increase the corona inception voltage (+7%) and give improved electrical endurance to PZT ceramic surfaces.
- The 2A53 material is stated by the manufacturer to meet the requirements of MIL-I-46058C. There is no similar qualification for the EN-2 material.
- The 2A53 material gives better adherence to the PZT surface.
- The acceptable operating temperature range for both materials exceeds the requirements for transducer use.
- The cured 2A53 material has lower water absorption, electrical dissipation factor, and dielectric constant than EN-2.
- The insulation resistance of 2A53 is approximately 50 times greater than for EN-2.
- The 2A53 coating material cures bubble-free without vacuum degasing. Conap indicates that EN-2 will do this also, but it does not appear to be fully satisfactory.
- The uncured 2A53 material has a lower viscosity rating and should flow more readily into microscopic crevices.
- The uncured 2A53 material has a longer pot-life and will allow manufacturing operations that are not time critical. The EN-2 material only works well for about thirty minutes.

This change in the construction of the AN/SQS-56 transducer should produce an electrically stronger transducer and make it easier for the contractor to pass the corona requirement in the finished product.

3.4. PLANS

- Measure the voltage endurance function on the Conap CE-1171 coating material.
- Study corona inception voltage (CIV) effects on various hook-up wire configurations used in transducers.

- Evaluate hook-up wire insulation materials for transducer use.

4. TASK C-1 - STANDARD FOR O-RING INSTALLATION

C.J. Sandwith - APL, University of Washington
G.D. Hugus - NRL-USRD

4.1. BACKGROUND

The reliability of sonar transducer arrays can be significantly improved by the adoption of standard procedures for the installation and assembly of O-ring seals. The problem is that no such standard procedure exists. Presently, the installation procedures are determined by the installer and the materials available at the time of installation.

The results of analyzing failures of O-ring seals in connectors used in underwater applications over decades show that roughly eight out of thirteen O-ring failures have resulted from improper installation and assembly or improper quality control and inspection procedures at the time of assembly. Stated another way, the results showed that even though O-ring seal design may be perfected by the proper O-ring type selection (piston, face, or crush) by the maximum crush section thickness, by selecting the proper O-ring size and material, and by using two O-rings in series (double O-rings) a substantial number of the O-ring failures will occur due to improper installation and inspection procedures.

4.2. OBJECTIVE

The objective is to provide a handbook containing a standard procedure for installing O-ring seals in electrical connectors and other undersea static applications.

4.3. PROGRESS

Work to fulfill this objective is being performed under contract by the Applied Physics Laboratory of the University of Washington.

From comments by reviewers and a survey of existing standards and specifications the scope of the handbook was changed. The main sections are now:

- Scope
- Purpose
- Definitions
- O-Ring Seals, General
- O-Ring Seal Problems
- O-Ring Seal Design and Material, General
- Installation
- Tools
- Inspection and Tests
- Packaging
- Storage and Aging
- Lubricants
- Reliability
- Bibliography

The scope of the handbook also has been changed to expand its audience to include O-ring installers, people involved in O-ring design, machinists, inspectors, and suppliers. Existing specifications were referenced for all given design, installation, and inspection information.

The final draft of the handbook is complete and is ready for publication. This task has been completed except for the final formal publication.

4.4. PLANS

Publication of the handbook as an NRL Memorandum Report will occur in the first quarter of FY82.

5. TASK C-2 - CABLE SHIELDING

H.W. Denny - Georgia Tech Engineering Experiment Station

5.1. BACKGROUND

Certain advantages such as better waterproofing, better water-blocking and lower cost would result from the use of underwater electrical cable without the internal shielding. The use of unshielded vs shielded cable has already been investigated from a mechanical strength viewpoint. The approach will now be to consider the electronics viewpoint of using unshielded or shielded cable on the outboard side of a submarine. Concerns are primarily centered upon electromagnetic interference and ground loops.

5.2. OBJECTIVE

The objective is to determine whether the use of unshielded cable in place of shielded cable, exterior to the hull of a submarine, will affect the electrical performance and reliability of sonar systems. Three tasks are associated with the accomplishment of this objective. These tasks are:

- Survey and analyze the installation of the DT-276 hydrophone of the BQR-7 and BQQ-5 systems on submarines to determine the electromagnetic interference (EMI) environment and the present practices of utilizing shielding on cables.

- Develop the theoretical modeling of shielded vs unshielded cables necessary and sufficient to predict the electrical performance and reliability of individual and arrays of DT-276 hydrophones in the EMI environment found exterior to the hull of a submarine.

- Devise and implement experimental procedures to verify the predictions from the second task.

5.3. PROGRESS

Determination of the electromagnetic environment to which outboard cables are exposed is proving to be a time consuming process. In July, a visit to Naval Sea Systems Command (NAVSEA) was made in connection with this task. Considerable information on physical layout and installation practices was obtained but very limited information on the environment, arising from either internal or external sources, was identified. Subsequent discussions with the personnel from the Naval Underwater Systems Center (NUSC) in New London, CT, indicate that perhaps definitive data on the external environment does exist. Formal requests for pertinent reports have been made; to date the reports have not been received. Telephone followup with NUSC has been made to emphasize the importance of this information.

In parallel with the first task, the second and third tasks were initiated to:

- Minimize the impact of the first task on the overall schedule, and

- Take advantage of favorable weather for outdoor measurements.

The second task, identification and assessment of theoretical approaches to the modeling of the sonar cables was initiated. An extensive literature search was conducted to locate possible models. The basic approach developed by Dr. Paul of the University of Kentucky seems to be the most applicable. Consequently, one of his analysis programs has been implemented and is being employed to analyze the base line problem of a pair of wires over a flat ground plane with air as the surrounding medium. (An examination of the effects of both fresh and saltwater on the coupling is planned.)

In addition to Dr. Paul's work, alternative analytical approaches continued to be assessed. In view of the above noted sparsity of data on the external environment, attention was focused on potential coupling of the internal electromagnetic environment to the external cable. Initially, it was postulated that internal fields (within the frequency region of interest) would be TEM in nature, arising from conductors traversing the vessel cylinder. Careful examination of a TEM-based solution, however, concluded that the basic assumptions associated with such a solution, namely, the existence of perfectly conducting cylinder walls, would prevent the generation of meaningful results. For example, if the external medium is non-conducting, the only contribution to the H-field in the exterior region is the displacement current. Where the conductivity of the outer shell is very high, but not infinite, the "quasi-TEM" mode is a valid approximation, and the displacement current is extremely small. If, however, the external medium is conductive, i.e., seawater (conductivity ≈ 4 $\mho$/m), then the contribution to the external magnetic field from the conduction current term in Ampere's Law is no longer zero. Indeed, it is likely that the conduction current term is much larger than the displacement current term. Efforts are underway to determine the magnitude of the conduction current. The results of this determination will be used to decide upon the course of the experimental efforts. If the conduction current term proves to be so small as to be practically immeasurable, then future analyses and measurements will stress coupling from external fields, both from environmental sources and from adjacent cables. However, if the conduction current term is large enough to give rise to measurable current on the external cable then experiments will be set up, in saltwater, to measure those currents.

To support the third task, a temporary water tank in which a simplified model of a submarine may be immersed has been designed and constructed. The dimensions of the tank are $4'h \times 4'w \times 16'l$. An existing aluminum cylinder, $1'd \times 12'l$, is planned to be used as a pseudo-simulation of the submarine. Although the aluminum will not behave electromagnetically the same as steel, it is expected that this simulation approach will allow independent validation of the analytical procedures and thus increase confidence in the results when the models are applied to a steel structure. The initial approach, predicated upon the need to measure internal-to-external coupling, is to obtain data on the submerged aluminum cylinder with its ends sealed. However, as discussed, the coupling to internal fields may be below the level of detectability, and in that case, the approach is likely to be to allow the cylinder to fill with water and then support it at a convenient depth for the measurement of external coupling. A set of preliminary measurements on a simple parallel line model in air, fresh water, and saltwater has been intitated for the purpose of refining the test setup and for performing the validation checks on Dr. Paul's transmission line coupling model.

5.4. PLANS

Plans for the first quarter FY82 are to:

- Emphasize the gathering on data on the electromagnetic environment of the exterior cables of submarines.
- Assess the magnitude of the conduction current term produced by internal fields.
- Complete the parallel line coupling analyses and measurements for air, fresh water, saltwater media.

6. TASK D-1 - ALTERNATIVE MATERIALS: PLASTICS

K. Niemiller - NWSC

6.1. BACKGROUND

Corrosion, cost and acoustic characteristics are parameters that must be considered when selecting a material for the design of a sonar transducer. In the past decade, plastics have decreased in cost and increased in strength to the point that they are in strong competition with metals for specific applications. Plastics could be used as a design material for sonar transducers in order to lower costs and lengthen service life if they can withstand the ocean environment. An additional advantage is that plastics generally are electrically nonconductive and acoustically transparent.

Specifically, the injection molded thermoplastics are the best materials for consideration as an alternative assembly material since they can be molded to close dimensional tolerances and in many configurations. Metals and electronic connectors can be molded directly into the plastics thus reducing the number of separable parts and insuring in-service reliability.

Naval facilities equipped with the proper molding equipment can fabricate replacement parts for sonar transducers when parts are not in stock or readily available. This would be extremely helpful when emergency repair is necessary and the time for normal procurement procedures is not available. In the event that a shortage of material should occur, thermoplastics can be easily recycled.

Presently there are no general long-term ocean immersion data available for thermoplastics. It would take many years of testing and analysis to determine the long-term life expectancy, but there is an immediate need for information. The only approach for determining this information in a reduced time period is to perform accelerated life testing (ALT), but this must be used with caution. When this method is used, it is always recommended that comparison be made to parts which have been exposed to the actual environment in question.

6.2. OBJECTIVE

The objective is to evaluate the ability of plastics to withstand an ocean environment and the reliability of the ALT method for use in determining long-term material life expectancy.

6.3. PROGRESS

The approach to the objective has been to perform a two-year equivalent ALT on eight types of glass-filled thermoplastics. Parallel to this, the same materials will be exposed to an ocean environment for two years. Water absorption, volume change, tensile and shear strength, and sound speed will be measured on all samples. A comparison of the results of the ALT and the ocean test will allow a prediction of the life expectancy of these plastics in sonar application.

Ocean tests are continuing on all eight glass-filled thermoplastics. One of these test materials, polyphenylene oxide/styrene, has completed one year exposure to the ocean environment. Tables 6.1 and 6.2 allow a comparison of the results from the previous ALT and the in-ocean test. On attempting to reduce this data it becomes obvious that experimental scatter is nearly as large as the observed changes. Figure 6.1 shows the change in shear strength with time and temperature. No trends are visible, except for the errors in measurement at 16 hours. Figure 6.2 does show trends in the tensile strength of this material. An Arrhenius-type plot of the time to 5% degradation in tensile strength is given in Fig. 6.3. A least square line through this data yields an energy of activation of 25.7 KJ/mole (6.1 Kcal/mole). This preliminary data reduction, therefore, would indicate that polyphenylene oxide/styrene is an attractive choice for underwater mounts in that it maintains its relatively high strength very well with exposure. In addition, the degradation process is relatively temperature insensitive.

Table 6.1 - Tensile Strength of Polyphenylene Oxide/ Styrene from ALT and Ocean Environments

ALT ENVIRONMENT

HOURS	TEMP (°C)	TENSILE STRENGTH (PSI)	SOUND SPEED (m/sec)
2	10	14,941	Not Tested
	25	15,833	
	45	15,368	
	75	15,399	
16	10	15,284	2452
	25	14,251	2405
	45	14,366	2434
	75	13,939	2392
64	10	16,370	2293
	25	16,110	2319
	45	15,226	2267
	75	15,441	2290
1024	10	14,866	Not Tested
	25	14,831	
	45	14,270	
	75	13,717	
2048	10	12,897	2329
	25	14,458	2316
	45	12,332	2299
	75	9,902	2285

OCEAN ENVIRONMENT

WEEKS	TENSILE STRENGTH (PSI)	SOUND SPEED (m/sec)
1	14,741	Not Tested
7	15,293	Not Tested
15	14,137	2283
31	14,843	Not Tested
52	14,912	2203

Baseline Tensile Strength = 15,768 psi, Sound Speed = 2224 m/sec

Table 6.2 - Shear Strength of Polyphenylene Oxide/ Styrene from ALT and Ocean Environments

ALT ENVIRONMENT

HOURS	TEMP (°C)	SHEAR STRENGTH (PSI)
2	10 25 45 75	8,644 8,650 8,519 8,653
16	10 25 45 75	8,319 7,934 7,744 8,222
64	10 25 45 75	8,761 8,944 8,693 8,618
1024	10 25 45 75	8,545 8,827 8,787 8,786
2048	10 25 45 75	8,441 8,501 8,715 8,736

OCEAN ENVIRONMENT

WEEKS	SHEAR STRENGTH (PSI)
1	8,844
7	8,639
15	8,587
31	8,807
52	8,668

Baseline Shear Strength = 8,463 psi

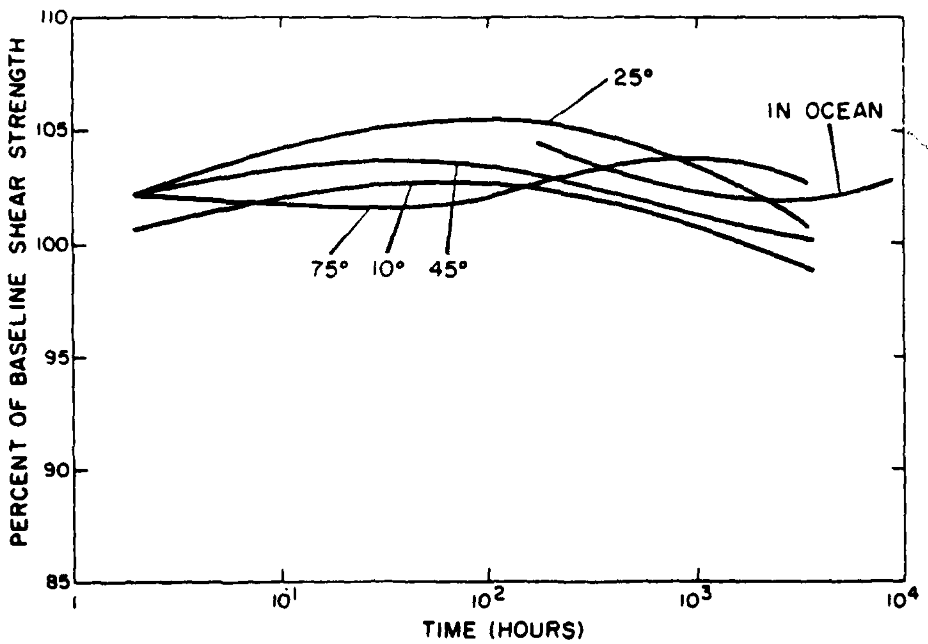


Fig. 6.1 - Change in shear strength of polyphenylene oxide/styrene

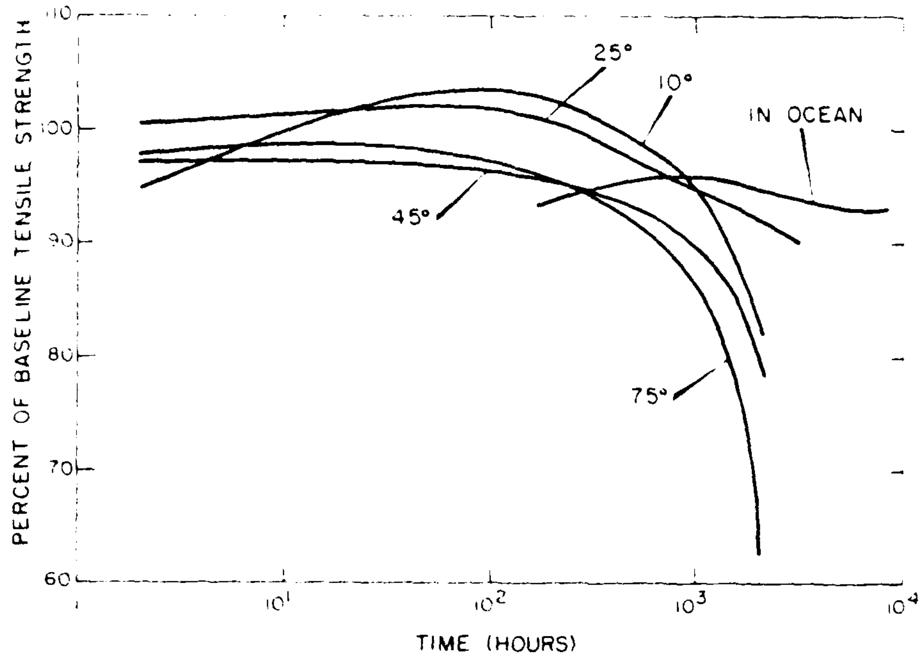


Fig. 6.2 - Change in tensile strength of polyphenylene oxide/styrene

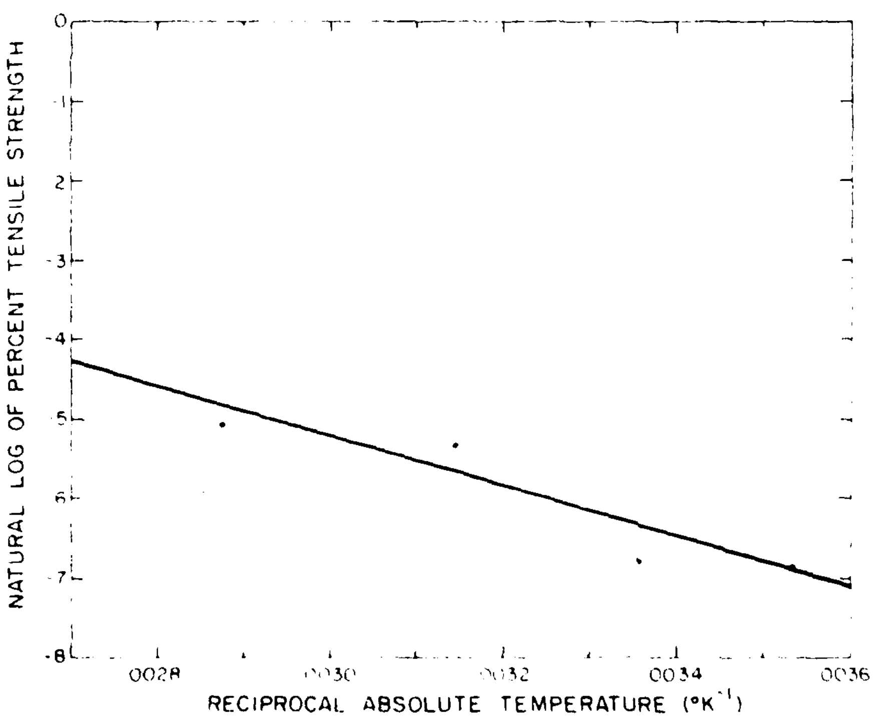


Fig. 6.3 - Arrhenius plot for time to 5% degradation in tensile strength

6.4. PLANS

- Continue ocean environment exposure.
- Conduct test of samples exposed to ocean environment for one year.
- Complete analysis of ALT data.
- Submit interim technical report on ALT findings.
- Prepare procedures for evaluating creep, stress degradation, and machined plastics degradation.

7. TASK D-3 - SPECIFICATION FOR TRANSDUCER ELASTOMERS

C.M. Thompson - NRL-USRD

7.1. BACKGROUND

The high cost of maintenance, replacement, and repair of fleet transducers has become so inhibitive that the reliability of sonar transducers has received a great deal of attention in recent years. Improvement in the reliability of such systems through failure analysis and material development and modification is emphasized. It is hoped that such an effort will, in the end, provide the fleet with more effective systems having an extended operational lifetime and also that the overall life cycle cost will be minimized. Indeed, the most severe stress that can be imposed on a system or the materials used in the system is that of time. The necessity of a transducer elastomer to maintain its physical strength, electrical resistivity, and acoustic properties in the face of years of temperature extremes, UV radiation, seawater, pollutants, and physical abuse is a most difficult requirement. Small wonder then that transducer elastomers have been the source of a large proportion of failures in sonar transducers.

The most frequent scenario for the choice of a transducer elastomer is that the design engineer, having developed a list of performance requirements, requests from a rubber manufacturer a material to meet these requirements. Unfortunately, the performance requirements are frequently, at best, an educated "guess" of the properties expected of the material based on past experiences. The requirements list may not include all of the important short-term properties and likely will not include any long-term properties. Consequently, the material developed by the rubber manufacturer is not likely to have been optimized for short-term operation; moreover, it may not even have been considered in its design for the extended lifetime performance required in a sonar transducer system.

A recent example of this type of failure has been with a neoprene rubber formulation which was designed to meet a variety of specification tests. Unfortunately, the specification did not require a high electrical resistance after water immersion and this deficiency has apparently produced an alarmingly high rate of transducer failure.

It is therefore desirable to establish specifications for transducer elastomers that are based on a consideration of all the stresses imposed. This requires that the performance of transducer elastomers, both initial and long-term properties, be well understood as functions of elastomer composition, cure conditions, and environmental parameters. Only then can the composition and processing procedures of the elastomers be carefully chosen and specified. In this task, the results obtained in other more basic R&D programs will be incorporated in the development of specifications for transducer elastomers. Appropriate engineering studies will also be carried out for candidate materials as needed so that the preparation of complete rubber specifications may be possible.

7.2. OBJECTIVE

The objective of this task is to establish specifications for elastomers designed for use as transducer windows and as cable jackets.

7.3. PROGRESS

7.3.1. Neoprene 5109 will be the subject of the first design specification for transducer elastomers. Previous work on this material under the aegis of the Sonar Transduction Sciences Program has demonstrated that this neoprene formulation exhibits basic properties that are adequate for underwater acoustic application. Instrumental techniques have also been developed for its compositional analysis. A set of statistically significant equations were developed in FY81 to establish the composition-property relationships. It has also been shown that Neoprene 5109 has a low water permeation rate (25 ng cm/cm^2 h torr - compared with 30-60 ng cm/cm^2 h torr for most neoprenes) as well as a stable and moderately high volume electrical resistivity (1×10^{10} ohm cm). Its formulation also suggests that the material exhibits good crystallization resistance, compression set, and bondability. The known problems with Neoprene 5109 are:

- The uncured rubber needs to be stored frozen, and
- The compound will only flow for a moderate period of time during molding.

Therefore, Neoprene 5109 may find applications in a variety of sonar transducers, provided that the material is handled and processed properly.

7.3.2. The study on the effects of composition changes on the transducer-related properties of neoprene elastomers is continuing. Emphasis during this quarter has been on the electrical resistivity and water permeability properties. Portions of these test results were presented at the TR-155F Failure Mode Analysis Workshops at the request of the Naval Sea Systems Command (SEA63X5). It is very difficult to measure the electrical resistivity of elastomers accurately and precisely. One reason for this non-reproducibility is the difficulty in separating surface from volume resistivity. Commercial equipments are now available which accomplish this separation by means of a guard electrode. A second problem with the instrumentation is the difficulty in attaining reproducible electrical contact. Sufficient pressure must be applied to deform any surface irregularities. The third, and perhaps the most difficult problem, lies in the nature of the samples themselves. Since the resistivity of rubber depends very strongly on the concentration of carbon black, any inhomogeneity of the sample may cause the test results to vary by one or more orders of magnitude. Consequently, great care is necessary to assure homogeneous samples.

Figure 7.1 shows the dependence of the resistivity of Neoprene GRT samples upon the concentration of SRF black. The resistivity of Neoprene GRT with varying carbon black particle size is shown in Fig. 7.2. The degree of carbon black loading is varied as well as the particle size to maintain a constant hardness. It was found that the resistivity decreases instead of increasing with decreasing particle size as one would normally expect. However, it is apparent from these results that careful selection of carbon black type will help in preparing a rubber with high resistivity.

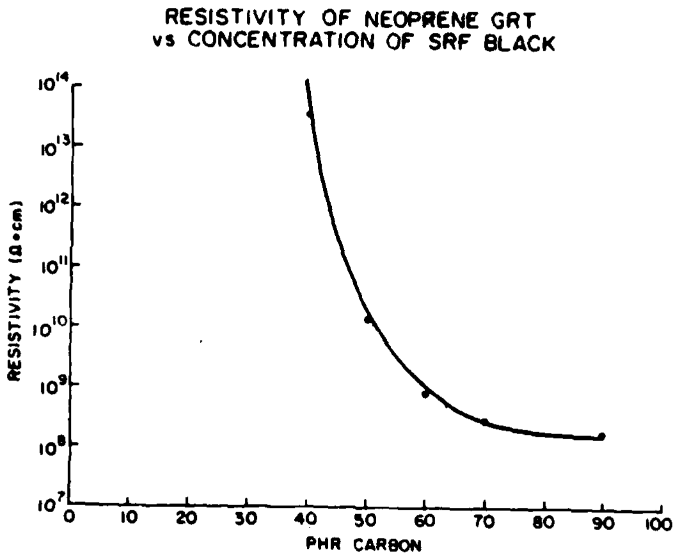


Fig. 7.1 - Resistivity of Neoprene GRT vs concentration of SRF black

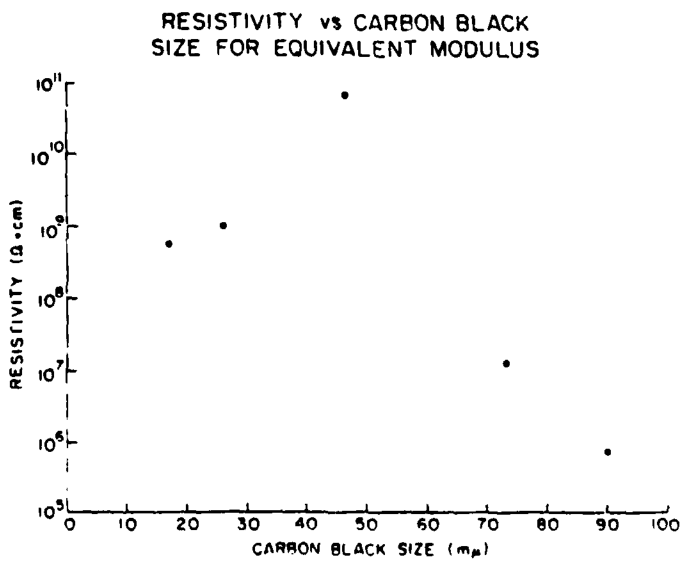


Fig. 7.2 - Resistivity vs carbon black size for equivalent modulus

Several investigators have noted a drastic decrease in electrical resistivity in the neoprene rubber used in TR-155F transducers after seawater exposure. To understand the mode of this decrease, a number of neoprene samples were designed and acquired to mimic the 155F formulation in various of its ingradients. The resistivity of these samples was monitored as a function of exposure time and temperature in water. Surprisingly, none of these samples has yet shown any decrease in resistivity as reported. Further testing will be performed for a variety of samples in seawater. Since the 155F rubber is a neoprene-butadiene mixture, similar samples will also be developed for testing.

7.4. PLANS

- Prepare a draft of the Neoprene 5109 specification (November 1981)

- Continue testing on the environmental resistance of Neoprene GRT and WRT formulations.

8. TASK D-4 - TRANSDUCER CERAMICS

A.C. Tims - NRL-USRD

8.1. BACKGROUND

Because of the fragile nature of piezoceramic ceramic materials, transducers using these materials are shock hardened by the technique of winding glass filament under tension onto the ceramic element to produce a constant compressional stress in the ceramic material. The compressional bias reduces the probability of tensional fracture of the ceramic when subjected to high acceleration due to explosive loading. However, variations in the winding technique may produce a variability in the finished transducer element that greatly exceeds any variability in the properties of the ceramic itself.

It is well known that fiber wrapping of ceramics causes significant changes in the electromechanical coupling coefficients k_{31} and k_{33}, and also changes in the capacitance and dissipation factor, but this investigation is not primarily concerned with these changes. This investigation is concerned with whether a specific group of ceramics will necessarily show greater statistical variations in properties after fiber prestressing than before.

8.2. OBJECTIVES

The objectives are to investigate and determine the effects of filament winding on piezoelectric ceramic in transducer configurations and to develop a standard procedure for the fiberglas wrap process used on ceramics in sonar transducers.

8.3. PROGRESS

There are several variables involved in the process that could potentially cause variations in the finished product such as filament material properties, resin type, wrapping tension, and resin cure cycle. However, it appears that there are two major causes for the variability between fiberglas-wrapped ceramics. The first may be due to variations in the winding tension from ceramic to ceramic. The second cause is probably intrinsic to the ceramic itself. If the diameters of the ceramic are not concentric, or the shape is ellipsoidal, the stresses in the wall will not be uniform. In this case, the winding tension could be constant from ceramic to ceramic but the end results would show greater variations in the electromechanical parameters after wrapping.

One way to test the latter hypothesis is to obtain ceramics of close dimension tolerances, prestress them, and statistically analyze the before and after prestress variations.

Twenty-two Type I ceramic cylinders with a wall thickness-to-diameter ratio of 0.05 were obtained. Each cylinder was cut in half to form two lots of 22 each or a total of 44 ceramics with outside radii of 2.6 cm, inside radii of 2.33 cm, and lengths of 3.13 cm. The mean difference in the measured outside diameters was 0.53 mm, the wall thickness .076 mm, and the length .063 mm. Thus the cylinders have close tolerances, are round, and have concentric inside and outside diameters. After the electromechanical parameters were measured the two lots of 22 each were sent to two manufacturers for prestressing, with one manufacturer receiving one half of the original cylinders and the other manufacturer receiving the other half. The specification sent to the manufacturers for the cylinders was: *The cylinders shall be prestressed to a magnitude equivalent to an external pressure of 3.58 to 4.38 MPa at the outside diameter of the cylinder.* This specification gives a bias prestress equivalent to about 1000 V or 10 V/mil across the ceramic. Only the magnitude of the prestress was specified leaving such things as the number of turns, number of layers, winding tension, resin and cure cycle, and roving type to the discretion of the manufacturer, but the manufacturers were to supply data on the discretionary items. Table 8.1 shows the manufacturers' data. There is not a significant difference in their process, but differences are noted such as differences in winding tension and cure cycle.

Table 8.1 - Manufacturers' Data

	MANUFACTURER A*	MANUFACTURER B**
Number of Turns	81	74
Number of Layers	3	3
Winding Tension	11.6 lbs	9 lbs
Resin-Curing Agent	Epon 828-D	Epon 815-D
Cure Cycle	>4 hrs @ 170°F	1-5 hrs @ 180°F 12 hrs cooling
Roving	Owens Corning P/N S-901-12	Owens Corning Fiberglass OCF 801AB-700 E Filament

* Manufacturer A is a small government contractor
** Manufacturer B is a large government contractor

After the prestressed elements were returned to the USRD their electromechanical parameters were measured again with the same equipment setup and measurement technique. The results of the before and after prestress measurements are shown in Table 8.2.

Table 8.2 - Results of Before & After Prestress Measurements

	f_m (Hz)	f_n (Hz)	k_{21} (%)	Q_m	C_{pF}	D (%)	
Before Glass Wrap	20383	21458	31 25	427	20919	1 50	Manufacturer A
Standard Deviation	187	178	0.73	103	734	1 49	
After Glass Wrap	21455	22320	27 50	715	19900	0 15	
Standard Deviation	169	161	0 56	74	510	0 11	
Before Glass Wrap	20390	21468	31 3	419	20870	1 19	Manufacturer B
Standard Deviation	194	187	0 7	113	593	1 05	
After Glass Wrap	22019	22610	22 69	529	18990	0 58	
Standard Deviation	191	181	0 94	54	480	0 40	

The standard deviations shown in Table 8.2 seem to indicate the ceramics are more uniform after prestress than before for both manufacturers. The Students' T test was used to test the hypothesis that the ceramics are of the same uniformity before and after prestress. There is sufficient statistical evidence, assuming normality, to reject this hypothesis and accept the alternate hypothesis which is that the ceramics are more uniform after prestressing. This conclusion is contrary to previously reported results and tends to support the conclusion that dimensionally close ceramics lead to more uniform end products.

There are some questions about the data that are unsolved. For instance, the mean coupling coefficient for manufacturer B is 17½% lower than that of manufacturer A. One would expect A to be lower since the ceramic was wound with more turns at a higher filament tension. Also, the standard deviation of the coupling coefficient is greater after prestress for B than before prestressing.

To gain more insight in prestressed ceramics and to provide a large statistical data base, a request has been made to add contract data requirements to the next SQS-56 buy. It has been requested that 300 ceramic stacks selected at random from the production lot (100 at the beginning of the production run, 100 from the middle, and 100 near the end) have their electromechanical values determined and recorded before the consolidated stack is fiberglas-wrapped and at least ten days after the stack is wrapped.

8.4. PLANS

- Develop an "in-house" fiber-wrap capability to give control over all phases of prestress process. Three hundred k_{33} mode TR-317/318 ceramics have been ordered to support this work.

- Determine a method for precisely controlling the winding tension from one transducer element to another.

- Interface with NUSC on the TR-317/318 procurement to get typed data included in the Contract Data Requirements list.

- Correlate variations in the electrical parameter of collected data to variations in prestress magnitude or process.

9. TASK E-1 - STANDARDIZED TEST PROCEDURE

J. Wong - NOSC

9.1. BACKGROUND

It is at present not possible to subject a transducer specimen to a series of environmental stresses over a short time period and prove, if it passes certain operating parameter tests, that the specimen is a reliable transducer with a certain minimum expected life in fleet use. Of course, if we could simply use a set of transducers for the desired fleet life, we could check the failure rates against acceptable replacement or repair rates; but the approach here is to accelerate the environmental stress actions and thereby subject the transducer specimen to seven years of life cycle stresses in a few weeks or months.

9.2. OBJECTIVE

The objective of this task is to develop a set of standardized procedures based on environmental stress requirements to accelerate the aging of transducers.

9.3. PROGRESS

Composite unit accelerated life testing (CUALT) on two Hazeltine Corporation DT-605 hydrophones (first article, serials A1 and A5) and two Ametek/Straza TR-316 projectors (first article, serials A1 and A3) continued. Five-years equivalent of CUALT have been completed for the two DT-605 hydrophones and the TR-316 projectors A1 and A3 have completed the second- and third-year equivalent of CUALT respectively.

Acoustic measurements on the two DT-605's were made after the completion of the fourth-year equivalent CUALT. The results were reported in the STRIP FY81 Third Quarter Progress Report.[1] A measurement error was discovered in the receive sensitivities of the wide-beam sections, staves 1 and 2, of serial A5 hydrophone (Fig. 9.4 in STRIP FY81 Third Quarter Progress Report). The erroneous data resulted when the maximum response axis of the hydrophone was not positioned correctly. Figure 9.1 shows the correct receive sensitivities of the wide-beam sections of DT-605, serial A5. Comparisons of the four-years equivalent of CUALT indicates that the wide-beam sections are still within specifications.

No acoustic measurements were performed after the completion of the fifth-year equivalent CUALT on the two DT-605's. These measurements will be made during the sixth-year equivalent, which has just begun with the thermal shock exposure as the initial exposure sequence. To date no oil leaks were detected in the two DT-605's.

Outputs terminated with 50-ohms resistors at end of 100 feet of 2SWF4 test cable.

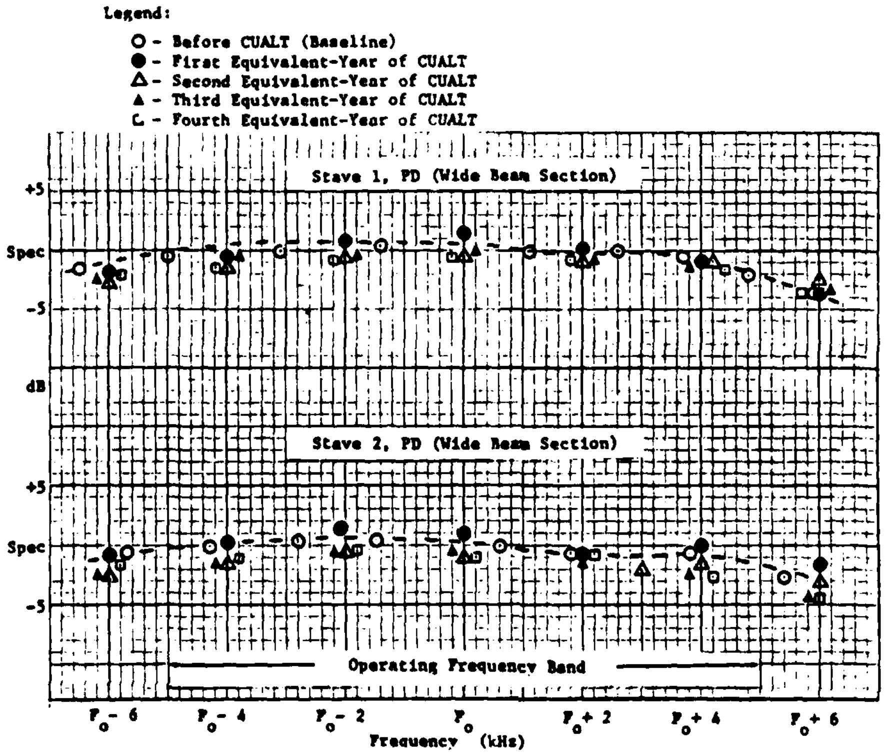


Fig. 9.1 - Receive sensitivity of Hazeltine DT-605 serial A5 after four-years equivalent CUALT

The TR-316 projector A3 has started the fourth-year equivalent with the thermal shock exposure and projector A1 is in the third-year equivalent with the pressure cycling and pressure dwell exposure completed. Figure 9.2 shows the durometer hardness, Shore A, of the neoprene acoustic windows of the two TR-316 vs the number of years equivalent of CUALT. The durometer values for each year equivalent were measured four to five days after the 71°C dry heat and ultraviolet (UV) exposure. A significant increase in the rubber hardness occurred at the end of the first-year equivalent, an increase of 10 to 15 Shore A values above the pre-CUALT measurements, for both TR-316 projectors. The exception is the new neoprene rubber on the up-beam section of serial A1 which was a replacement for the one ruptured during the first 68 hours of 71°C heat and UV exposure. The increase is less severe between the first- and the second-year equivalents, with an increase of only about five Shore A numbers. At the end of the third-year equivalent the rubber hardness for serial A3 appears to have reached a plateau with little or no increase above the values measured at the end of the second-year equivalent of CUALT.

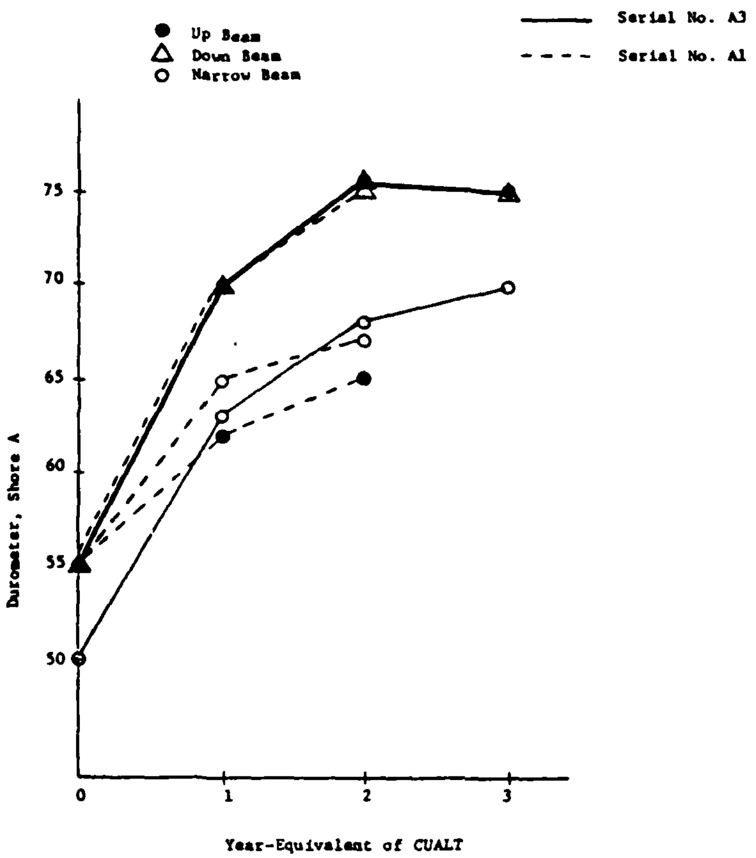


Fig. 9.2 - Durometer hardness of neoprene acoustic windows of TR-316 projectors

A technical report on the results of the FY80-81 CUALT effort is being prepared for publication.

9.4. PLANS

- Continue with CUALT on the DT-605 hydrophones to complete seven-years equivalent of CUALT between the first and second quarters of FY82.

- Continue with CUALT on the TR-316 projectors and complete as many as possible of the seven-years equivalent CUALT.

- Coordinate the evaluation efforts of TRI on the effectiveness of CUALT on lifetime predictions for the two aged DT-605's.

10. TASK E-2 - ACCELERATED LIFE TEST VERIFICATION

A. Phipps and *D. Steele - NWSC*

10.1. BACKGROUND

Until recently, sonar transducers used in the fleet were fabricated and put into operation with limited-life testing. Some units performed quite well throughout the expected service life while others exhibited an early high-failure rate. Costs of transducers have increased dramatically and the life requirements have been increased to fit new overhaul schedules. These and other factors have mandated verifying the reliability of units for the entire service life. In order to determine the reliability of transducers for a given time of service, it was determined that the approach of composite unit accelerated life tests (CUALT) should be used. This method not only investigates the physical degradation of the materials used in the transducer assembly, but also the susceptibility of mechanical or electrical failures. Just as accelerated life tests (ALT) for materials need to be verified by using specimens that have been exposed for the full d· ation to the environment being evaluated, this must also be done for CUALT.

In July 1978, a complete array of 48 DT-168B hydrophones was removed from the USS STONEWALL JACKSON (SSBN-634) and retained intact for post-service evaluation at the Naval Underwater Systems Center (NUSC), New London, CT. This array of hydrophones had undergone extensive evaluation at NUSC before being installed in the SSBN-634. It was decided that these hydrophones could be used to verify the acceptability of using CUALT for hydrophones.

The DT-168B is the passive sensor for the AN/BQR-2 sonar system. This set of 48 hydrophones was fabricated by the Naval Weapons Support Center, Crane, IN, in 1972. Three sets of five air-backed cylindrical ceramics made of lead-zirconate-titanate (PZT-5A) wired in parallel series are the main internal electrical components. The ceramics are protected by a steel cage that is covered by a butyl rubber acoustic window. The elements are isolated from the cage by rubber grommets. Shielded DSS-3 cable 38-m long is used to connect each hydrophone to the system.

By fabricating ten hydrophone units identical to those in the array and performing an established CUALT on these units, it will be possible to compare the degradation of these units to the information retrieved from the post-service hydrophones.

10.2. OBJECTIVE

The objective is to verify the accuracy of the CUALT method by comparing results with a known real-time life test.

10.3. PROGRESS

The DT-168B hydrophones have now completed the ALT portion of the CUALT test plan. The six cycles of saltwater immersion and pressure cycling were completed in September 1981 and performance testing was begun to determine the amount of deviation from the readings taken during qualification performance testing.

Insulation resistance readings were taken after each portion of the test sequence. Tables 10.1 through 10.3 show values for insulation resistance that were recorded during CUALT. The column headings indicate the test sequence followed. The production tests included capacitance, dissipation, null balance, impedance, and insulation resistance. The hydro column indicates readings taken after completion of the hydrostatic pressure test. Qualification tests included oven aging, vacuum, cold temperature, vibration and pressure cycling. Beam patterns, null balance, capacitance, impedance and insulation resistance were the lake tests which were conducted after the cables were cut to 65 feet and connectors were installed. The remaining columns indicate readings taken after each cycle of the ALT.

Data such as are shown in the tables will be evaluated and compared to data from the post-service hydrophones to determine the effectiveness of the CUALT for DT-168B hydrophones. A final report will follow after final measurements are completed and the data are evaluated.

Table 10.1 - Insulation Resistance (GΩ)
Black-White

S/N	PROD	HYDRO	QUAL	LAKE	CYCLE 1	CYCLE 2	CYCLE 3	CYCLE 4	CYCLE 5	CYCLE 6
1	12.0	4.70	2.35	1.10	0.090	0.167	0.355	0.610	0.630	0.487
2	12.3	5.14	2.10	1.11	0.980	0.912	1.09	0.990	0.970	0.820
3	13.0	5.90	2.00	4.2MΩ	0.690	0.582	0.738	0.770	0.770	0.560
4	13.5	4.85	2.20	1.19	0.450	0.720	0.817	0.890	0.950	0.730
5	14.5	4.54	2.05	1.00	0.041	0.354	0.535	0.545	0.555	0.396
6	14.0	5.65	1.85	1.16	1.12	1.02	1.40	1.09	1.10	0.715
7	13.5	5.65	1.59	1.13	0.196	0.728	0.932	0.940	0.900	0.751
8	13.5	4.54	2.15	1.12	0.510	0.830	0.895	0.920	0.930	0.705
10	13.2	5.26	1.53	1.08	0.880	0.270	1.05	1.20	0.920	0.720
0124		0.515	0.91	1.00	---	---	---	---	---	---
0147		0.520	1.07	1.01	0.910	1.00	0.950	0.880	0.800	0.600

Table 10.2 - Insulation Resistance (GΩ)
White-Case

S/N	PROD	HYDRO	QUAL	LAKE	CYCLE 1	CYCLE 2	CYCLE 3	CYCLE 4	CYCLE 5	CYCLE 6
1	3.00	3.83	0.50	0.310	0.225	0.055	0.200	0.223	0.213	0.172
2	3.10	4.00	0.49	0.280	0.240	0.213	0.247	0.216	0.215	0.183
3	2.95	4.68	0.49	0.195	0.221	0.180	0.207	0.193	0.196	0.142
4	3.00	3.76	0.50	0.300	0.226	0.252	0.218	0.225	0.233	0.181
5	2.90	3.57	0.49	0.270	0.190	0.185	0.212	0.192	0.193	0.151
6	3.00	4.40	0.46	0.280	0.255	0.233	0.228	0.222	0.217	0.184
7	2.95	6.50	0.42	0.280	0.200	0.228	0.205	0.212	0.196	0.164
8	3.10	3.65	0.49	0.270	0.205	0.240	0.205	0.200	0.200	0.153
10	3.10	4.45	0.41	0.270	0.208	0.240	0.224	0.238	0.214	0.166
0124		0.565	0.31	0.270	---	---	---	---	---	---
0147		0.600	0.32	0.265	0.235	0.283	0.222	0.208	0.217	0.158

Table 10.3 - Insulation Resistance (GΩ)
Black-Case

S/N	PROD	HYDRO	QUAL	LAKE	CYCLE 1	CYCLE 2	CYCLE 3	CYCLE 4	CYCLE 5	CYCLE 6
1	2.85	5.83	1.25	0.780	0.325	0.295	0.410	0.590	0.578	0.472
2	3.00	6.11	1.02	0.810	0.780	0.800	0.910	0.850	0.860	0.732
3	2.90	5.90	1.18	0.215	0.650	0.520	0.670	0.680	0.660	0.508
4	2.85	5.99	1.26	0.840	0.460	0.648	0.712	0.780	0.820	0.652
5	2.90	5.61	1.25	0.750	0.230	0.360	0.525	0.520	0.540	0.395
6	2.90	6.80	1.06	0.830	0.990	0.875	0.962	0.960	0.960	0.741
7	2.95	3.95	0.95	0.845	0.320	0.640	0.815	0.820	0.780	0.680
8	3.00	5.99	1.21	0.800	0.550	0.700	0.769	0.800	0.820	0.630
10	3.00	6.08	0.93	0.800	0.720	0.120	0.848	0.870	0.790	0.630
0124		1.96	0.67	0.715	---	---	---	---	---	---
0147		1.97	0.68	0.725	0.690	0.800	0.760	0.725	0.740	0.535

10.4. PLANS

- Complete final measurements.
- Evaluate the hydrophones and data for degradation of physical and electrical properties.
- Compare the test data with that of the post-service hydrophones for determination of CUALT effectiveness.
- Final report.

11. TASK F-1 - ENGINEERING ANALYSIS: FAILURE MODES DUE TO WATER

P.F. Cassidy - Texas Research Institute, Inc.

11.1. BACKGROUND

The state of water which enters a transducer and its effects once inside are continuing problems in the sonar community. Important questions are:

- What impurities come through rubber seals with water permeation?

- Where is the internal water, adsorbed or vapor?

- What temperatures or heat flows occur within transducers when the ambient temperature changes or the device is driven?

- What value is desiccant in a transducer?

- How can the lifetime of a transducer be accelerated?

11.2. OBJECTIVE

The objective is to determine the effects of water or water vapor on the performance and lifetime of sonar transducers and hydrophones. Specifically, the effects of the neoprene seals on the permeant (and vice versa) and the electronic changes caused by the permeant are to be investigated.

11.3. PROGRESS

11.3.1. Water Effects on TR-208A Transducers

Two TR-208A elements which had undergone wet aging and characterization were thoroughly dried and retested. This was done to determine the ability of the transducer to recover from the accelerated life testing (ALT) process. Figure 11.1 is the free-field voltage sensitivity (FFVS) curve for one element which is characteristic of both elements and also of the transmitting current response (TCR) curves for both. It is evident that thorough drying can cause an essentially complete recovery of the transducer to its original characteristics from a rather severe change. This says that changes caused by humidity are reversible and transducers can be recovered, at least for this case within the limitations of the test.

Another question remained, that of the effect of aging the transducer in the dry state compared to aging with a high internal relative humidity. To answer this, a TR-208A element has been dried and is being aged in an oven at 70°C. At the end of thirty days the transducer will be characterized at NRL-USRD.

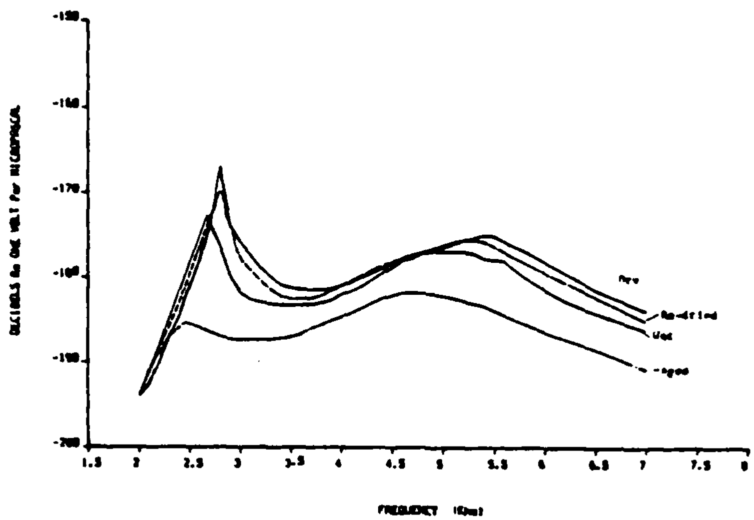


Fig. 11.1 - Free-field voltage sensitivity
TR-208 transducer serial 16955

11.3.2. Water Permeation Through Elastomers

Long-term (201 and 316 days) high temperature (60°C) permeation experiments with both deionized water (DI) and saltwater and Neoprene G were terminated and data were analyzed. Saltwater data showed a constant permeation rate of 1.43 to 1.44 mg/cm^2/day. However, the DI water did not reach a constant value, beginning at 1.51 and 1.69 and progressing to 1.63 and 2.35 mg/cm^2/day respectively for the two samples. The rate increased continuously throughout the test. A plot of $\Delta m/\Delta t$ vs t showed some scatter in the DI water data, but also confirmed the increasing permeation rate with time. The final data are summarized in Table 11.1.

Table 11.1 - Long-Term Permeation Results

	TOTAL TIME (DAYS)	TOTAL WATER PERMEATED (GRAMS)	CONDUCTIVITY OF FACE WASH* ($ohm^{-1}cm^{-1}$)	PERMEATION RATE† ($mg/cm^2/day$)	COMMENT
1st SET					
DI	316	16.53	8.6×10^{-6}	1.69/2.35	Permeant was pale yellow.
SALT	316	11.51	7.6×10^{-6}	1.43	Permeant was pale yellow with solids present.
2nd SET					
DI	201	8.10	6.6×10^{-6}	1.51/1.63	Permeant was pale yellow.
SALT	201	7.47	1.1×10^{-5}	1.44	Permeant was pale yellow.

* Pure DI water is about 5×10^{-6} $ohm^{-1}cm^{-1}$
† For DI water initial and final rates are given

A wash of the outer face of the rubber samples gave no indication of any soluble salts being transported to the surface by transgressing permeant. Samples of the Neoprene rubber which had undergone long-term extraction (316 days at [illegible]) were subjected to analysis by emission spectroscopy for cations; the data are summarized in Table 11.2.

Table 11.2 - [illegible] Analysis of Permeated Neoprene

DETERMINATION	CONTROL (UNUSED)	PERMEATED BY SALTWATER	PERMEATED BY DI WATER
% Ash	[illegible]	34	30
Na*	[illegible]	0.3 (0.10)	0.04 (0.01)

* The first value [illegible] given is the approximate percent in the ash. The second value in parentheses is the percent in the original rubber sample.

Conclusions drawn from these analyses are:

- Most metals are not removed by the permeant by dissolution into the residual water. These metals include Al, Ba, B, Ca, Cr, Cu, Fe, P, Mg, Mn, Ni, Si, Sr, Ti and V.

- Both salt and DI water remove sodium from the rubber, the former leaching out 17% and the latter leaching [illegible] of the sodium.

The difference in the amount of sodium removed from the rubber by the permeation and extraction experiments shows that the effect of water permeating a transducer boot is still not completely understood. Additional rubber samples of known composition will be subjected to long-term tests, and composition vs depth will be explored in order to get a better picture of water permeants effects.

A new rubber of known formulation is being sought for additional permeation tests. These new experiments will be done to verify the non-equilibrium permeation rates observed earlier at 60°C with DI water. Burke Rubber Company has provided three samples of Neoprene identified as

- GRP #5109
- GNA #5010
- GNA/WHV #5057

They ranged by thickness from [illegible] to 0.080 inches, much thinner than samples used in earlier tests. Samples were cut from each of these and placed on ASTM cups containing water, and the units were placed in a desiccator at 80°C. Apparent equilibrium was reached after approximately forty hours. The relative permeation rates are in order of sample numbers 1 : 1.27 : 1.45. The lowest of these is the same material being tested by NRL-USRD.

11.3.3. Water Effects on X-308 Transducers

Two X-308 elements have been dried and one was filled with dry castor oil. Then sufficient water was injected to raise the relative humidity (RH) to 90%. The other element was flushed with 89% RH to equilibrium. Both transducers were then placed in a 70°C oven for accelerated aging and they were monitored by plotting impedance loops after each week of aging. Figure 11.2 demonstrates a regular and significant progression (expansion of the loop) of data commensurate with time at elevated temperature.

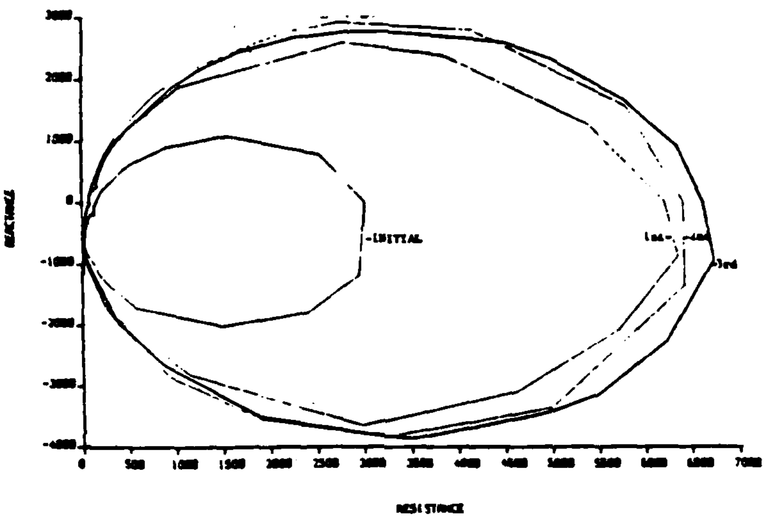


Fig. 11.2 - Impedance loops for third week ALT

11.4. PLANS

- A TR-208A element aged in the dry state for 30 days at 70°C will be characterized and data will be compared to those from humid aging.
- New rubber samples (Neoprene G, specially formulated) will be subjected to accelerated permeation (at elevated temperatures) with both DI and saltwater. The elastomers will then be analyzed.
- Interior water adsorption data will be taken for the X308 transducers.
- Accelerated aging for X-308 transducers (both air- and castor oil-filled) will be completed.

12. TASK F-2 - ENGINEERING ANALYSIS: CERAMIC STACK JOINTS

C.L. [illegible] and [illegible] Bohman - NOSC

12.1. BACKGROUND

A severe deterioration in the electroacoustic performance of piezoelectric ceramic stacks that are assembled with epoxy adhesives has been observed at elevated temperatures that are due to either the environment or self-heating. Initial investigation has indicated that this degradation can be attributed partly, if not wholly, to a softening of the cement holding the ceramic stack together when high temperatures are encountered.

12.2. OBJECTIVES

The objectives are to identify and quantify the temperature dependent parameters of cements and ceramics that are used in transducer fabrications, to develop optimum cement joint configurations and fabrication techniques, and to develop math models of cement layers for use in transducer element design that accounts for the configuration of the cement joints as well as the temperature dependence of the cement.

12.3. PROGRESS

An interim report of the cement joint investigation has been written and will be distributed as a Naval Ocean Systems Center (NOSC) Technical Report (TR). The report covers the cement joint problem from its discovery during composite unit accelerated life testing (CUALT) in 1979 through the ensuing investigative work in 1980 and 1981.

Concerning the infrared (IR) surface temperature measurements of operating resonators, the emissivity difficulty has been solved by painting a strip of flat black paint along the resonator. Since the entire painted surface has a constant emissivity of approximately one, absolute temperature can be measured along the entire length of the resonator. Figure 12.1 shows results measured from a resonator being driven at 20 V peak. The results should be viewed in conjunction with stress or power loss analysis on the resonator computer model. The result in Fig. 12.1 does not by itself comment on the cement joint losses for a resonator in air. Figure 12.2 shows results for the same resonator painted and unpainted. For this data an IR sensor emissivity setting of 0.2 was used. This increases the sensitivity of the sensor but at the expense of temperature calibration, thus the voltage output of the IR sensor replaces the temperature on the vertical axis of the plot. It is clear that many of the pronounced changes in the unpainted results are due to emissivity differences between the resonator components. The electrical and thermal properties of the paint do not affect the resonator operation. The IR sensor spot size shown in the STRIP FY81 Third Quarter Progress Report[1] was 0.127 cm as stated by the manufacture specifications. However, from a practical viewpoint the spot size has been measured to be approximately 0.3 cm as shown in this report.

In conjunction with a separate task, methods for measuring ceramic and cement-joint parameters, as a function of temperature, have been decided on for FY82 measurements. Ceramic parameters will be measured as a function of temperature by measurements of various resonances and anti-resonances of rings and discs in an oven. Cement-joint parameters will be obtained as a function of temperature by resonance measurements of two steel rods individually and cemented together. Ceramic discs measured previously can be included in the rod assemblies for the purpose of excitation in the oven.

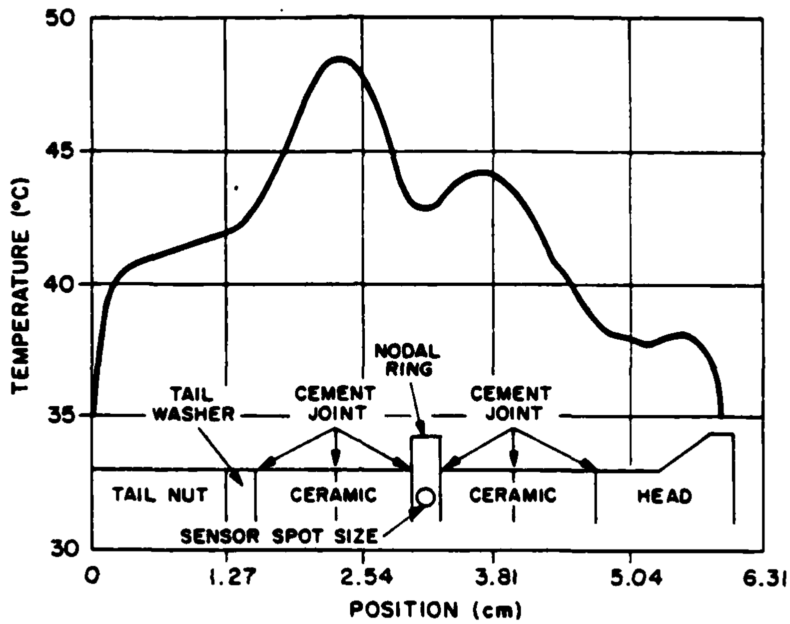


Fig. 12.1 - Longitudinal, infrared temperature profiles of an unloaded piezoelectric ceramic stack resonator, in air, with the emissivity taken to be unity along the entire resonator and drive voltage at 20 V peak.

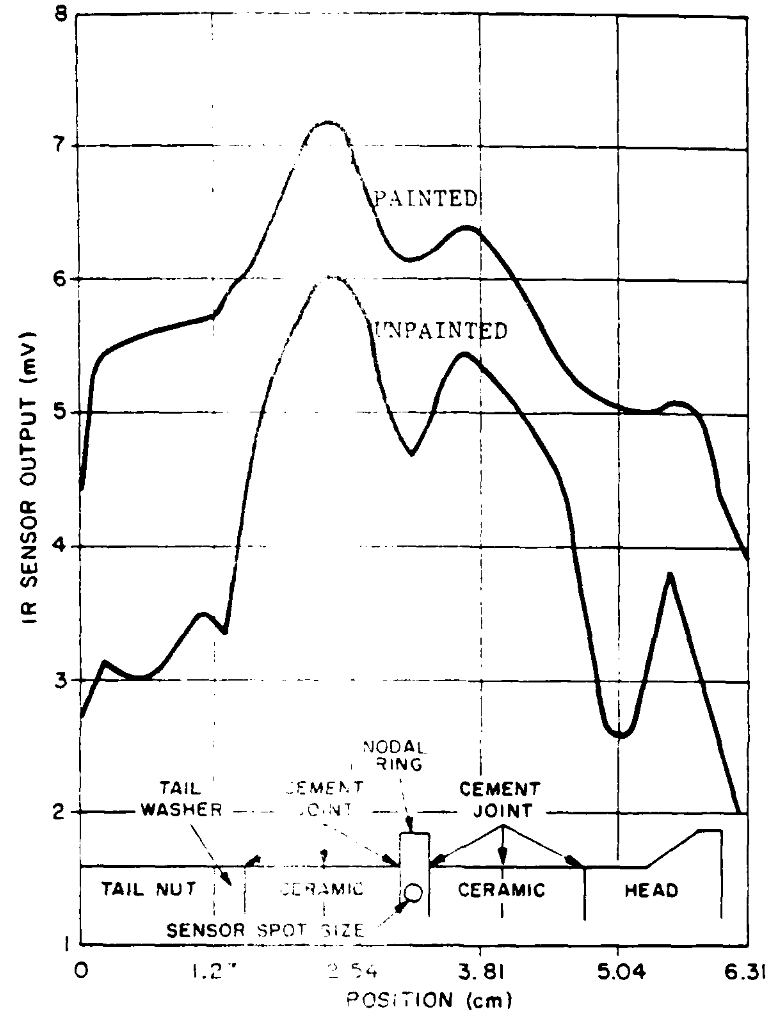


Fig. 12.2 - Infrared sensor scan of the resonator driven in air at 20 V peak along painted surface strip (emissivity constant) and unpainted surface (emissivity variable).

IR temperature measurements have been taken for dummy-loaded resonators under high drive; however, further measurements and analysis are required before the results can be distributed.

12.4. PLANS

- Ceramic and cement/electrode joint parameters will be measured as a function of temperature using techniques whose development was the focus of a separate task in FY81. The measurements are expected to begin sometime in November 1982.

- The ceramic and cement joint parameters vs temperature data base will be applied to the computer model of a ceramic stack resonator in order to evaluate the resonator's performance as a function of temperature. The IR measurements of dummy-loaded resonators may be used to select the proper temperature dependent parameter values.

- The impact of the above results will be investigated with regard to design and assembly techniques that will reduce the temperature degradation effects of cement joints in ceramic stack resonators.

- Design input to the TR-316 and SQS-56 product fabrication specifications will be provided.

13. TASK F-3 - RELIABILITY AND LIFE PREDICTION SPECIFICATION

R.L. Smith and *D. Barrett - Texas Research Institute, Inc.*

13.1. BACKGROUND

The need for military equipment of high reliability is fairly obvious both in terms of meeting mission objectives and cost effectiveness. This situation has long been recognized of course and a heroic infrastructure developed to deal with it. In the military procurement setting one small slice of conventional wisdom - the exponential model - has been extracted for use from a large and diversified body of information. This choice is not injudicious but is confining. The exponential model, although only one of many alternatives, is probably the reliability description of most fundamental importance for two reasons:

- The exponential model correctly describes the length-of-life behavior of components whose resistance to loss of function in service or under load (strength in a generalized sense) is not time dependent, provided the same operating environment (statistical stress distribution) is experienced throughout the use period.

- Complex systems tend to be exponentially reliable even if their components are not themselves individually exponential.

The exponential reliability description is also referred to as the random hazard model because the hazard function or per unit time probability of failure is constant in time. This has some interesting implications. For example, the probability of successfully completing a mission is independent of the age of the item involved. Also, preventive maintenance has no meaning; a component remains as good as new until some overstress abruptly alters its condition to a failed state. There are many products such as electronic components, glassware, and pottery for which this is a reasonable description. In contrast, many basic materials (rubber, steel, chemicals, etc.) degrade during storage, environmental exposure, and use resulting in a time dependent reliability description termed wearout. Systems assembled from components drawn from either category can exhibit an overall exponential reliability behavior. In such a case the underlying randomness is a result of structural heterogeneity or perhaps repair strategy rather than stationary properties. The exponential model could just as well be called the maximum ignorance model because all process dynamics information and all associations of cause and effect are suppressed. One ignores the details of their origins and asks only on the average how often failure occurs.

In the military procurement setting, exponential modeling in the form of either the Part Stress Analysis or Parts Count methods (per MIL-HDBK-217C) is the nearly universal reliability description tool. Part Stress Analysis recognizes that the parameter of the exponential model, although time independent, does depend strongly on a variety of loading or stress, quality, and use conditions. Even at this level of sophistication an important feature is missing. No measure of the precision of the output or dispersion estimate is provided by the handbook reliability methods.

Reliability is the probability that an item will perform successfully under stated conditions. As such, it cannot be directly measured for a single component but must be inferred from the behavior of a population of similar devices that have seen similar service. Even if the components tested are truly identical (a pedagogical idealization), the determination of the parameter of the parent population is limited by the statistics of sampling. One would like to see handbook entries qualified on this basis, but they are not. Since the similar items tested are in fact not identical, further refinement calls for incorporating this overall properties dispersion into the modeling description. The "constant" parameter of the exponential model becomes more properly a distributed random variable.

It should be recognized that any reliability description, be it exponential or a wearout model, is of limited usefulness by itself. Rather, supplemental information in the form of failure analyses and physics-of-failure studies are required if product improvement strategies are to be developed. Recognition of this is slowly diffusing down from policy-making levels within the US Navy. W.J. Willoughby, Jr., Deputy Chief of Naval Material for Reliability, Maintainability, and Quality Assurance, states it dramatically: "There is no such thing as a random failure!"[3] This does not rule out the exponential (random hazard) model as totally inappropriate. Willoughby is saying that failures have causes and fixes (which represent a higher art form than figuring out something is wrong) that invariably require some detail work.

13.2. OBJECTIVES

The general project objectives are to extend and clarify the proper scope of exponential modeling and to identify and characterize wearout processes in standard sonar transducer applications. This is being done to permit more realistic and therefore useful and effective specifications of reliability requirements in support of sonar procurements. More specifically, the immediate objectives for this project, broken down by category, are:

- Extend the Failure Modes and Effects Analysis (FMEA) approach to cataloging hardware vulnerabilities to include type identification of wearout and random hazard modes.

- Model four different degradation processes: water permeation, bond-line degradation, fatigue, and corrosion. This involves the synthesis of time-to-failure distributions by incorporating kinetic process characterizations into a probabilistic design reliability description.

- Develop a description of the dispersion properties of exponential modeling and apply the results to to DT-513A preamplifier.

- Perform a combined random hazard and wearout evaluation of the DT-276 hydrophone.

- Attempt to understand and evaluate the methods of Bayesian inference for use in the sonar setting. (The Bayesian method associates a prior probability distribution based on previous experience, with reliability modeling parameters, and conditions via testing to construct a modified or posterior distribution.)

13.3. PROGRESS

The extended Failure Modes and Effects Analysis of the DT-276 hydrophone has been completed and a detailed report will be provided in the next reporting period. The procedure was developed from MIL-STD-1629, and was expanded to include some additional detail in the breakdown of failure modes and mechanisms specifically recognizing the differences between wear-out and random-hazard types of failures. Table 13.1 shows the column headings for the MIL-STD-1629 worksheet and the extended worksheet indicating the type of development.

Table 13.1 - Worksheet Column Headings

MIL-STD-1629	Extended Form
Output Specification	Component and Function
Functional Description	
Failure Mode	Failure
Serial Number	Serial Number
Description	Mode
Possible Causes	Cause
	Mechanism
	Random
	Wearout
	Time Dependency
Detectability/Symptoms	Detectability/Symptoms
Effect of Failure	Effect of Failure
Local	Local
	Next Up
End	End
Compensating Provision	Backup/Compensating Provision
Level of Severity	Level of Severity
Failure Probability	Failure Probability
Notes	Notes

The FMEA procedure allows for quantitative measures of failures and their probabilities of occurrence. In many cases these numerical data were not available and qualitative indicators were substituted. Thus the reliability indicators frequently took the form of subjective estimates based on the experience of the user community with this hydrophone and the types of failures seen. In this simple system, this procedure tends to produce predictable results from the analysis. For example, very few failures of the solder joints to the pins have been encountered in service, so that failure mode is given a low probability estimate. Thus the FMEA is structured to allow the incorporation of whatever operational experience with the system of interest is available. Hopefully, this enhances the value of this technique in focusing attention on residual defects.

The initial result of the FMEA is to highlight those situations in which the combination of severity and probability is unacceptably high. The extended FMEA conducted on the DT-276 produced the initial result shown in Table 13.2. The criterion for "unacceptably high" was any rating combination of 2-3 or higher, i.e., a severity of two with a probability of three or 3-3, 2-4, 3-4, or 4-4. This analysis treats only the hydrophone and does not include the Portsmouth connector or any splices.

Table 13.2 - Failure Modes Having Unacceptable Severity/Probability

COMPONENT	SERIAL NO.	FAILURE MODE	CAUSE	SEVERITY	PROBABILITY
Molding Rubber	3.2-2	Conductive	Formulation	3	2
Cable Assembly	3.1.1-2	Flooded Sleeve	Bond Loss	4	2

In the last STRIP quarterly report[1] considerable discussion was devoted to developing the dispersion aspects of exponential reliability modeling. Work in this project area is now complete and has resulted in a manuscript[4] which has been submitted for publication. Quite a surprising result has surfaced in examining the reliability modeling impact of poorly defined failure times. The maximum likelihood estimator of the exponential modeling parameter depends only on the total equipment operating or exposure time. In many situations this quantity remains reasonably sharply defined although the observed failure times carry large uncertainties individually. Thus far only the exponential model, and more specifically the situation where no more than one failure per observation interval is observed, has been analyzed. However, there is a strong indication that the acquisition of routine inspection data can be interpreted in bona fide life testing terms in less restrictive settings. Work applying these distributional ideas to the DT-513A preamplifier as a specific example is in progress.

13.4. PLANS

Plans for the next reporting period call for delivering the FMEA task report, completing the DT-513A example, executing the degradation modeling task, and completing the DT-276 methods application study.

14. TASK F-4 - FAILURE MODES ANALYSIS AND IMPROVEMENTS FOR TR-122

E.W. Thomas - NRL-USRD

14.1. BACKGROUND

The TR-122A/B (BQC-1) transducers are two-way communication devices installed aboard all US Navy submarines. In addition to the communication function, there is a built-in homing device for emergency use. This class of transducer was designed and built by the Dyna-Empire Corporation and has been in use on US submarines for many years. They are filled with a solution of dimethyl silicone oil, containing 83% Dow Corning 550 and 17% Dow Corning 200-10, that serves as an acoustic coupler between the seawater and the sensing elements of the transducer. One of the major disadvantages of using silicone oil is that the low surface tension causes it to creep continuously throughout the servicing area in the Transducer Repair Facilities of the Naval Shipyards. This insidious creepage results in a coating of a monomolecular-thick film of oil on all the exposed areas of the transducers, molds, cables, connectors, and associated hardware, which results in weak and unacceptable rubber molds and bonds, cement mixes, and elastomer fabrication.

Previous study suggests that substitution of Baker dB-grade castor oil for dimethyl silicone oil as the coupling fluid in the TR-122 transducer is not recommended. The study also indicates that in addition to the poor handling characteristics of the coupling fluid, that the operating characteristics of the transducer were borderline. The transducer has a poor record of meeting the published specifications.

14.2. OBJECTIVES

The objectives are to analyze the failure modes of the TR-122 (BQC-1) and to develop, test, and evaluate an improved replacement transducer.

14.3. PROGRESS

Sufficient internal components to assemble several TR-122X transducers were obtained. The modification of two TR-122X transducers was completed and tested at the Mare Island Transducer Repair Facility (TRF). The results of the initial acoustic tests on the transducers were shown in the STRIP FY81 Third Quarter Progress Report.[1] The comparison of the actual curves to the predicted curves was very favorable and all values were well within the specifications for the TR-122 transducers. Shock tests were conducted at Hunter's Point Shock Test Facility, San Francisco, CA, on 4 through 7 May 1981. Post shock physical inspection revealed minor damage to the pressure release corprene backing, but subsequent acoustical measurements showed the transducers still met pre-shock specifications. The results are shown in Figs. 14.1 through 14.4.

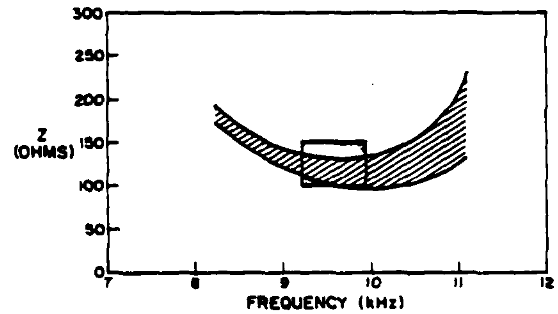


Fig. 14.1 - Open shaded area includes all combinations of impedance vs frequency over a range of temperatures and hydrostatic pressures at 3 to 30°C and 40 to 6895 kPa (4 to 700 m). In order to meet specifications the curve must pass through close shaded rectangular box at some point.

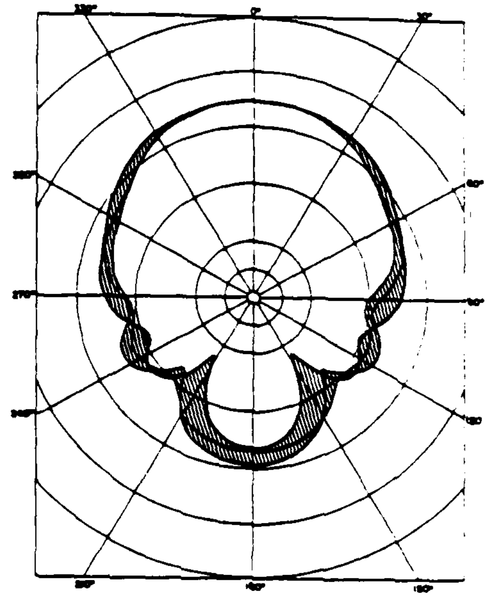


Fig. 14.2 - Directional Response at 9.6 kHz. Shaded area includes all combinations of temperatures and hydrostatic pressures at 0 to 70°C and 40 to 6895 kPa (4 to 700 m).

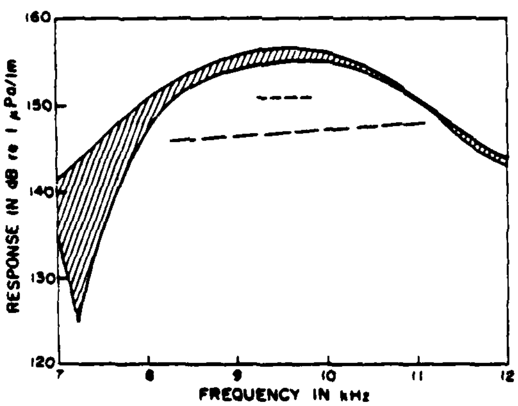


Fig. 14.3 - TVR vs Frequency. Shaded area includes all combinations of response over a range of temperatures and hydrostatic pressures 0 to 30°C and 40 to 6895 kPa (4 to 700 m). Dashed lines indicate minimum response levels between 8.3 and 11.1 kHz.

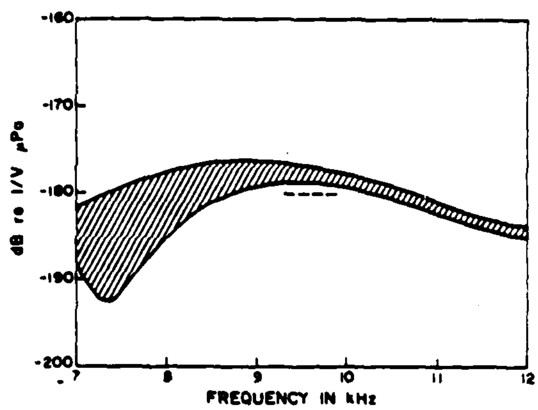


Fig. 14.4 - Free-Field Voltage Sensitivity. Shaded area includes all combinations of sensitivities over a range of temperatures and hydrostatic pressures 3 to 30°C and 40 to 6895 kPa (4 to 700 m). Dashed line indicates minimum sensitivity level between 9.3 and 9.9 kHz.

The conclusion of this task is that an improved replacement transducer for the TR-122A/B now exists.

- The internal components of the Dyna-Empire Corp. model 55 transducer, as built for the Trident, can be fitted into the case of the TR-122A/B with minimal machining.

- The resulting transducer, designated in this task as the TR-122X, has successfully met all performance specifications both before and after explosive shock tests.

- The Mare Island TRF has successfully demonstrated the ability to modify the TR-122A/B cases, assemble and install the model 55 components, and therefore produce a high quality, improved transducer.

- It is recommended that the TR-122X be accepted as the improved replacement to the TR-122A/B.

14.4. PLANS

No further plans. This task has been successfully completed.

15. TASK F-5 - ENGINEERING ANALYSIS: METAL MATRIX COMPOSITES

O.L. Akervold - Honeywell, Inc.

15.1. BACKGROUND

The main reason for considering metal matrix composites is to increase the bandwidth of the transducer. The bandwidth of the transducer is inversely related to the total energy stored in the vibrating system. If the stored energy is reduced in relation to the energy dissipated per cycle then the bandwidth will be increased. There is energy stored in the head, the ceramic, the tail, and some in the acoustic field. Of these, the head is unique because its velocity is the same velocity that flows into the load. So, in addition to the head being located where the velocity is maximum, that velocity cannot be reduced without reducing the energy radiated. Therefore the only way to minimize its stored energy is to reduce its mass. This mass reduction is what the metal matrix composite material is expected to provide.

15.2. OBJECTIVE

The objective is to quantitatively compare and experimentally demonstrate the performance improvement possible with metal matrix composite materials for the head of longitudinal vibrator elements.

15.3. PROGRESS

The progress has been in forming the detailed plans and in establishing coordination with Navy programs of similar content to maximize the benefit to the Navy.

<u>Computer Analysis Method</u>. The planned finite element analysis of the head is well within the current state of analysis capability. The program "ANSYS" is well suited to this task. This program is available from either of two sources locally. Each of these sources can also provide, if so desired, personnel for consultation or to execute the full calculation. ANSYS will be used through one of these sources.

It has been suggested that the Naval Ocean Systems Center (NOSC) in San Diego, CA, has a program which will make calculations of head motion and that it might be made available to benefit this program. At this time it appears that that facility has a heavy workload and will not be available to this program in the desired time frame.

Jan Lindberg at the Naval Underwater Systems Center (NUSC) in New London, CT, has a program task to evaluate composite material for vibrator heads for application to a particular torpedo transducer. A part of that program is to calculate, using finite element techniques, the motion of different heads for the torpedo transducer. This will include heads of both conventional and silicon carbide particulate filled material. Close coordination between that effort and this program is needed to prevent useless duplication of effort and to maximize the benefit to the Navy. The details of the Navy effort are expected to be firmed up in the next few weeks. We will be in communication during this time period to provide the desired coordination. Some adjustment to the tasks or schedule for this program are likely to result from that effort.

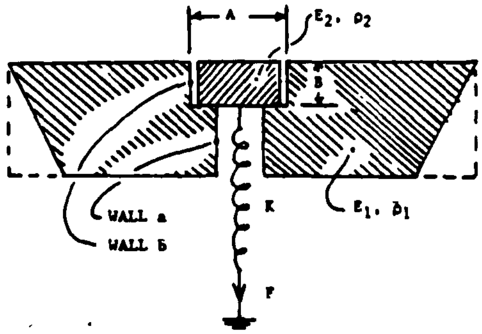
Head Configuration To Be Evaluated. The previous reports have stated the general range of head configurations to be studied. These cover head diameter values from 0.25λ to 1.0λ and head thickness to diameter ratios of 1/6 to 4/10. A detailed tabulation of the particular dimensions resulting from these ranges is shown in Table 15.1. Note that the table shows that configurations both with and without a stress bolt will be evaluated. Figure 15.1 shows how the stress bolt effect will be included. It is clear from Fig. 15.1 that with a thin head the presence of the stress bolt would have a significant effect on the resulting performance.

The table shows a set of 48 runs. It is planned that these 48 runs will be made both for the conventional and for the metal matrix composite head material. Once trends are established, however, it is quite possible that not all of the runs would have to be made to fully determine the desired vibrational performance.

Table 15.1 - Matrix of Head Conditions Planned for Computer Evaluation

RUN NOS.	HEAD THICKNESS	HEAD DIAMETER		STRESS BOLT IN HEAD		O.D. OF DRIVE CERAMICS
		FRONT	REAR	YES	NO	
UNITS	cm	cm	cm	--	--	cm
1,2	1.27	7.62	7.62	X	X	2.54
3,4	1.90					
5,6	2.54					
7,8	3.18					
9,10	1.27					3.81
11,12	1.90					
13,14	2.54					
15,16	3.18					
17,18	1.27					5.08
19,20	1.90					
21,22	2.54					
23,24	3.18					
25,26	1.27		2.54			2.54
27,28	1.90					
29,30	2.54					
31,32	3.18					
33,34	1.27		3.81			3.81
35,36	1.90					
37,38	2.54					
39,40	3.18					
41,42	1.27		5.08			5.08
43,44	1.90					
45,46	2.54					
47,48	3.18					

NOTE: In all cases runs would be made for both conventional aluminum and for SiCp-Al head materials.



- o Force, F, constant (not a function of head displacement)
- o No constraint on Wall a
- o No constraint on Wall b
- o A = 1.59 cm
- o B = one half head thickness
- o E_1, ρ_1 of head material
- o E_2, ρ_2 of steel
- o K is effective stiffness of the stress bolt
- o F net force on head generated by bolt

Fig. 15.1 - Geometry for incorporation of stress bolt in head calculations

Calculations To Be Made. It is planned to evaluate the defined cases over the frequency band from 5000 to 25000 Hz. Within this band the following would be determined:

- The frequency of all flexural resonances
- The displacement curve at each resonance
- Displacement curves at selected frequency points below and between the resonances

Procurement of SiCp-Al Material. A quote has been received from DWA for 12 pieces of 40% VO material. The pieces are 7.62 cm in diameter and of four different thicknesses: 1.27, 1.90, 2.54, and 3.18 cm. The delivery for this material is eight to ten weeks. Mr. Lindberg has also indicated that some residual material might be available from NUSC. If this is available and applicable, it will be used to replace or supplement material procured from DWA.

Methods Of Head Velocity Measurement. The proposed method of measuring the displacement of experimental heads to confirm the calculations is by use of an optical Fotonic Sensor. This will be used for the primary displacement measurement. However, it measures only one point at a time and does not give a real-time picture of the head motion. Mr. Lindberg is planning to restore, at NUSC, equipment for examining vibrating surfaces using holography. This would provide a real-time picture of the full head motion at once. If this is available in time for this program, some of the models will be examined holographically and compared to the Fotonic Sensor measurements.

15.4. PLANS

The following tasks are planned for the next quarter:

- Review the Navy's specific plans for their torpedo transducer head analysis and relate them to this program to provide for maximum benefit to the Navy.
- Request a contract delivery date change from December 1981 to March 1982 to allow coordination with the Navy program.
- Revise the program schedule as required.
- Start and complete head analysis calculations.
- Select a source and order metal matrix material for head fabrication.
- Complete the design of the test vibrator(s) and order the ceramic material.

16. TASK F-6 - IMPROVED HYDROPHONE ANALYSIS

J.A. Parkes - NWSC

16.1. BACKGROUND

It has been found that the DT-276 hydrophone is not the perfect sensor to be used with the BQQ-5 and BQR-7 sonar systems. If a hydrophone could be developed that meets all the system requirements of the BQQ-5 and BQR-7, eliminates the current DT-276 shortcomings, and adds findings from STRIP, it will be the optimum replacement sensor for the DT-276.

16.2. OBJECTIVE

The objective is to provide the engineering analysis and development of an improved, more reliable hydrophone for use in sonar systems such as the BQQ-5 and BQR-7.

16.3. PROGRESS

16.3.1. Introduction. This task will apply STRIP results to meet the objective. The approach is to assess and define the current DT-276 shortcomings through the review of the FY81 STRIP task "Improved Hydrophone Analysis (DT-276)."[1,5] Additionally, the results of a FY81 DT-276 hydrophone study are being used to establish performance requirements, alternative hydrophones, and design changes. In the future, information from the FY82 STRIP tasks "DT-276( ) Reliability Prediction", "Transducer Elastomers", and "Unshielded Cables" will be essential to this task and thereby will require continuous exchange of findings.

16.3.2. Analysis Of Fleet Returned DT-276's. The results of detailed STRIP failure analysis of DT-276 hydrophones removed from various submarines showed the following most prominent problem areas:

- Water entering the cable.
- Water migrating into feed-thru sleeve.
- Boots not bonded to ceramic cylinder and end caps.
- Cracked ceramic cylinders.
- Moisture inside hydrophone.
- Moisture in connectors.
- Improperly manufactured cable splices.

16.3.3. DT-276 Hydrophone Study[6]

<u>Conclusions and Recommendations</u>. A conclusion that no short-term requirement exists to upgrade the DT-276 hydrophone specification requirements was drawn after a review of current AN/BQQ-5 and AN/BQR-7 sonar system requirements. The limiting factors at this time are local noise, flow noise, number of staves, stave locations and arrangements, and, in

particular with the AN/BQQ-5, the beamforming technique. As the sonar system's processing capability is improved it is anticipated a long-term improvement requirement will exist to increase input signal sensitivity.

If an immediate replacement for the DT-276 is required, either the DT-513 or DT-574 can be used. Both units have the same basic sensitivity requirements as the DT-276, however, each will require some system modifications. The most acceptable unit in terms of system adaptability would be the DT-574. However, the short cable length (50 feet) and the requirement for new mounting brackets make this a costly replacement. The DT-513, in addition to new mounting brackets, will require some electronic redesign of the inputs to both the AN/BQQ-5 and AN/BQR-7. The redesign will be necessitated because of the preamplifier located in the hydrophone wet end. In both cases no apparent performance gain is realized for the dollar output. It would be far better to put the time and effort into an upgrade program for the DT-276. This upgrade program might be broken into two categories: improving reliability and possibly improving sensitivity. The reliability program should address:

- Bonding materials
- Cable lengths
- Electronic breakdowns
- Wet end connectors on both ends of the cable
- Ceramic breakdowns
- Replacement criteria

The sensitivity issue may address:

- Beamwidths
- Summing techniques
- In-hydrophone preamplifiers

Recommendations based upon the current user system requirements are presented as follows:

- Make full use of the STRIP task to develop a new generic rubber specification and incorporate it into an improved DT-276.
- Investigate the use of a nonconducting and non-acoustic degrading maintenance barrier on the ceramic assembly prior to rubber molding.
- Investigate an improved cable/ceramic termination method.

- Investigate the design of a short, compliant, and water-blocked pigtail cable to be molded to the hydrophone.

- Investigate the selection of a reliable, water-blocked in-line connector to be rubber-molded between the hydrophone pigtail cable and the cable run to the Portsmouth connector.

- Investigate the reconfiguration of the hydrophone ceramic cylinders into two separate cylinders mounted and wired to provide some degree of vertical vibration cancellation and yet maintain the existing receiving characteristic.

- Review the need to consider improvements in the existing hydrophone mounting brackets to achieve improvement in the horizontal vibration coupling from hull to hydrophone.

- Consider a preamplifier incorporated into the hydrophone only if it can be clearly demonstrated that this is the only way to overcome on-board noise pickup problems. This would require a relative expensive change to the front end of the user systems.

- Consider including in all investigations the effect of various summing techniques.

- Consider upgrading the current DT-276 specification into a single configuration management product procurement baseline package.

16.4. PLANS

- Define physical and performance requirements.

- Obtain input from supporting work units and develop preliminary design and drawings.

- Develop reliability prediction, quality control plan, and production procedures. Formal design review.

- Complete preliminary design and start prototype construction.

17. TASK F-7 - ENGINEERING DOCUMENTATION

R.W. Timme - NRL-USRD

17.1. BACKGROUND

Each of the other program tasks is expected to be fully documented as an essential part of that particular task. This task will provide an overview. It will link together the various tasks. It will insure that the failures as well as the successes will be discussed. The aim is to help avoid the continued "reinvention-of-the-wheel." All too often in the past, developments and redesigns that have resulted in successful hardware have not been documented in terms of why certain materials and/or construction details are chosen over others. Later, the same decisions must be remade. Based on the results of this program, consideration will be given to procurement via construction specifications rather than performance specifications. The approach here will be to determine and document the proper RDT&E of transducers and hydrophones as required for future acquisition.

17.2. OBJECTIVE

The objective of this task is to provide direction and documentation of the technology of transducer design and engineering that results from this program.

17.3. PROGRESS

The STRIP will be reorganized for the coming fiscal year for several reasons. There has been a certain awkwardness with the present organization in that new work units did not fit well, certain areas were ignored, management could not be expanded, and the important link to the user was weak. In addition, the existence of a separate STEN program, which was a spin-off from STRIP, gave the appearance of too many unrelated transducer R&D programs. Furthermore, there has been a significant change in the government's acquisition strategy which must be supported. A decision has been made to acquire transducers by design specification rather than performance specification. There are many arguments for each procurement strategy and it is inappropriate to argue them here. Given the decision - what should STRIP address? The STRIP must be a technology base which is not too different from what we have been doing previously in STRIP, STEN, and the TR-155F investigation. The key is to have confidence that the design specification is accurate and complete. From knowledge of when new or improved transducers are needed, it is necessary to plan through time so that the various R&D efforts are completed and put into a design package that is exercised in a sample buy, which is evaluated, and proven before going into production.

To support this acquisition strategy, the following program plan has been approved by the Naval Sea Systems Command (SEA63X5) for the FY82 STRIP. The program will be funded at the $1725K level in FY82. The FY82 Program Plan for STRIP is included in this report as Appendix A.

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1. R.W. Timme, "Sonar Transducer Reliability Improvement Program (STRIP) FY81 Third Quarter Progress Report," NRL Memorandum Report 4543, 1981.

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3. W.J. Willoughby, private communication. Also see - W.J. Willoughby, "View From The Top," Military Electronics/Countermeasures, p. 14, 1980 - for general discussion.

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5. R.W. Timme, "Sonar Transducer Reliability Improvement Program (STRIP) Second Quarter Progress," NRL Memorandum Report 4487, 1981.

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APPENDIX A

FY82 PROGRAM PLAN

for

SONAR TRANSDUCER RELIABILITY IMPROVEMENTS PROGRAM

(STRIP)

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USRD

PROGRAM PLAN
FOR
SONAR TRANSDUCER RELIABILITY IMPROVEMENTS
FOR FY82

Prepared by
Naval Research Laboratory (Code 5970)
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for
Naval Sea Systems Command (SEA63X5)

Naval Research Laboratory
Underwater Sound Reference Detachment
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Program Plan
Sonar Transducer Reliability Improvements

1. INTRODUCTION

1.1 PURPOSE

The primary purpose of this program is to develop Critical Item Product Fabrication Specifications to support the acquisition of reliable, cost-effective fleet sonar transducers. This program will provide the technology base necessary to develop, test, and evaluate improved transducer designs, materials, components, and piece-parts that will meet specified requirements in the operational environment during the entire useful life of the transducer.

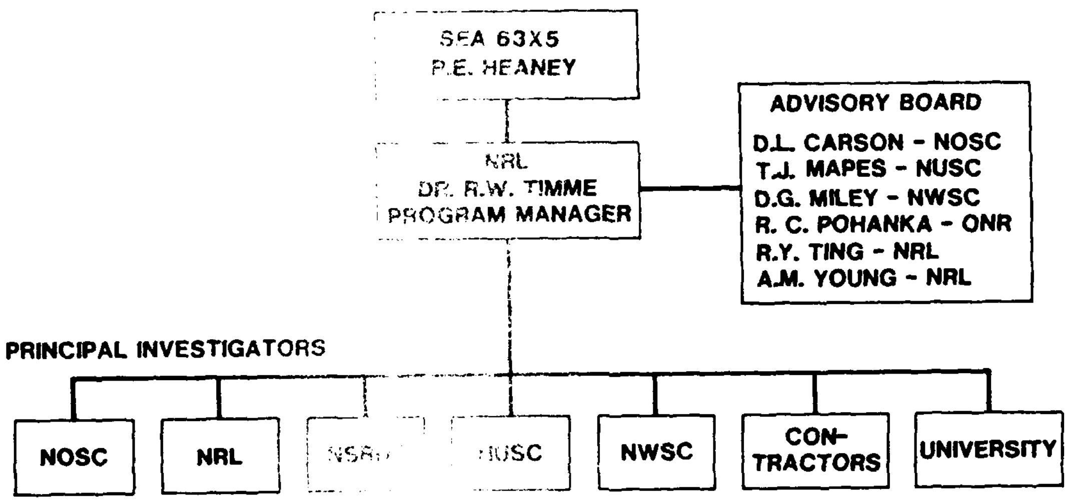
The output of this program will consist of the specifications, standards, and formal documentation for the materials, components, and processes necessary for the design, test evaluation, and ultimate procurement of reliable fleet transducers. These deliverables will define the required chemical composition and mechanical properties of materials, interpret gathered reliability data to define failure rates and mechanisms, define assembly, quality control, and diagnostic procedures, and define the required methods for the performance and lifetime evaluation of transducers.

1.2 MANAGEMENT BACKGROUND

In years prior to FY78, portions of this work were performed by various labs under mixed sponsorship. Starting in FY78, sponsorship was consolidated in NAVSEA 63X-5 and block funded to NRL-USRD. From FY78 through FY81, this block program was a part of Program Element 64503N (Submarine Sonar Development). Beginning in FY82, upon direction by NAVSEA63X, STRIP will be reorganized to include the Sonar Transducer Extraneous Noise Program and certain elements of other transducer failure investigations and improvement programs in a single transducer improvement effort.

Program management has been delegated to Dr. R.W. Timme, the Head of the Transducer Branch (Code 5970) of the Underwater Sound Reference Detachment, Naval Research Laboratory. He is responsible for negotiating program objectives with SEA63X5 and for formulating a program to meet those objectives. This formulation involves extensive dialogue between the Program Manager, an advisory board (composed of representatives from NOSC, NUSC, NWSC, ONR, and NRL), the principal investigators, NRL management, and other personnel in Navy activities with needs and expertise involving sonar transducer problems and reliability improvements.

This is a Navy-wide program involving all of the Navy Laboratories with a chartered interest in electroacoustic transducers and related sonar systems, as is shown in Fig. 1. In order to reach a successful conclusion, several project areas and individual work units require, and will be supported by, the more basic categories of research and development within the Navy. It is a management function to ensure that this support between different level programs take place. Current examples of such cross-fertilization are: STRIP will provide the 6.4 effort in a five-year R&D effort addressing the [illegible] 6.4 work on elastomers; and the strong interaction between managers and the principal investigators in STRIP and the Transduction Sciences Program (sponsored by SEA63R and managed by NOSC).



Program Management

2. PROGRAM PLAN

2.1 BACKGROUND

The sonar transducers currently in the fleet were designed 10 to 20 years ago on urgent high priority procurements without the necessary RDT&E efforts and without the technology base to make such efforts effective. The results have been time dependent degradation, high failure rates, excessive restoration and replacement costs, and frequent emergencies. It is not uncommon for 25% or more of the transducer elements of a sonar system to be nonfunctional after one or two years due to a variety of causes. Efforts to apply modern transducer technology have been reasonably successful, but the urgent response to fleet problems is necessarily limited to solutions that can be implemented in production without delay. Those solutions requiring extensive developments, tests, and evaluations have necessarily been neglected since they cannot be applied immediately to a production requirement. There is a need for a well organized RDT&E program to provide the technology base for the acquisition of transducers with improved design and reliability. This program will result in improved performance, increased reliability, and reduced unit life costs through better utilization and a more comprehensive characterization of materials, design techniques, and design data.

Upon direction from NAVMAT 06, future fleet transducer acquisitions are to be by design specification rather than simply performance specification. Although the technical content of the program will be little affected, this shift in acquisition strategy will have a significant impact on the long-range program plan. Procurement by design specification will mean that the priority for individual work units within the program must reflect the technical requirements of the acquisition schedule. That is, from knowledge of when new or improved transducers are required, the program is planned so that the needed investigations are completed and put into a design package which is exercised in a sample transducer procurement, evaluated, and proven before going into production.

2.2 OBJECTIVES

The primary objective of this program is to support fleet acquisition strategies by providing the technology base for the development of overall transducer design specifications through: the definition of extraneous noise criteria, the definition of reliability and life prediction models, the analysis of failure modes, the collection of a statistical data base, the characterization and specification of materials, the development and application of new design concept and diagnostic procedures, and the development/application of methods and facilities for accelerated life testing and extraneous noise T&E measurements.

2.3 ORGANIZATION

The program is organized into four major Task Areas, each of which contains several Project Areas, and, in turn, each one of which will contain several specific Work Units that will change each year in response to milestones established by the acquisition requirements. The organizational structure is shown in Fig. 2. The major Task Areas and corresponding Project Areas will be discussed in this section while the individual Work Units are discussed in Section 3.

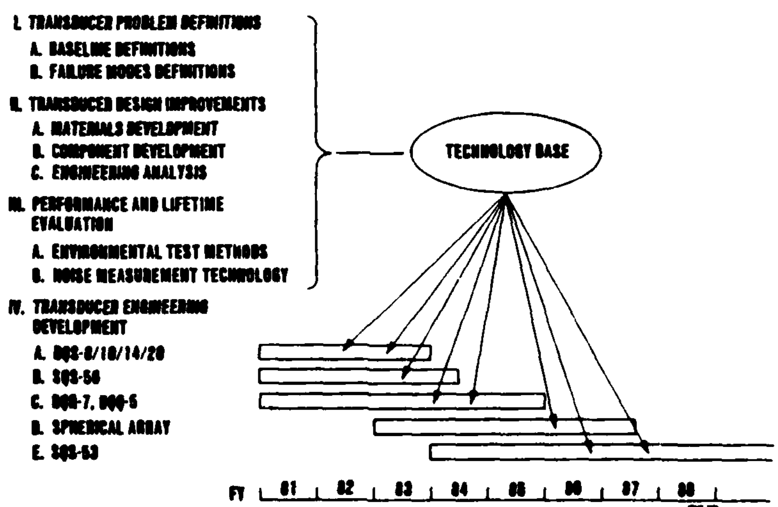


Fig. 2 - Sonar Transducer Reliability Improvement Program

2.3.1 Task Area I: Tra[illegible] Problem Definitions

The Baseline [illegible] Project Area will have the following objective: to gather, [illegible] and correlate information from all sources, especially the fleet, [illegible] transducer operations, practices, types of failure, envir[illegible] history, maintenance, extraneous noise, and impact of such noise [illegible] of defining a baseline of failure and acceptable performance [illegible] improvements can be guided.

Deliverables will [illegible] and specification of extraneous noise threat, determination [illegible] relation functions, data base for cause-effect correlations, [illegible] life prediction models, reliability specifications for t[illegible] requirements, quality control guidelines, and guidance for desi[illegible] and the development of each new transducer type.

The Failure Mode [illegible] Project Area will have the following objective: to analyze [illegible] terize transducer failure modes, mechanisms and dynamics of failur[illegible] purpose of providing direction to the R&D needed for improved tr[illegible]

Deliverables will [illegible] problem materials needing correction, reports of faulty de[illegible] materials and design development, values of hazard rates [illegible] of time for lifetime determination, and guides to accepta[illegible] designs and materials.

2.3.2 Task Area II: [illegible] Design Improvements

The Materials [illegible] Project Area will have the following objective: to develop [illegible] characterize materials so that more nearly optimum and reproducible [illegible] can be made and to provide the proper specifications of compo[illegible] processing, and quality control procedures for the applications [illegible] is to design and production of improved transducer developments.

Deliverables will [illegible] cations for neoprene, butyl, and nitrile rubber, encapsulants, [illegible] etric ceramics and the complete characterization of al[illegible] materials such as plastics and composites for incorporation into [illegible] transducer design specification. Deliverables will be d[illegible] linked to the development of the designs of new fleet transducers.

The Component [illegible] Project Area will have the following objective: to evaluate [illegible] er designs, materials, components, and piece-parts, including [illegible] connectors, proposed for use in new or improved transducers, to [illegible] quantitative alternatives with respect to reliability, ease of [illegible] ture, ease of quality control, availability of materials and immin[illegible], and incorrect assembly.

Deliverables will be reports of corona control materials and design procedures, specifications of high voltages and tolerances, specifications for improved cables and connectors, proven design, and diagnostic test procedures and standards for transducer assembly for application to the improved fleet transducers.

The Engineering Analysis Project Area will have the following objectives: to develop and utilize math models to predict transducer operation, to make quantitative comparisons between predictions and evaluation results to understand and solve unexpected results, to provide guidance to R&D in materials, components, and noise, to provide contingency capability for coping with future problem areas and to provide engineering documentation interfacing the systems applications and R&D efforts.

Deliverables will be engineering reports on design specifications and performance of improved fleet transducers and documentation of the entire program.

2.3.3 Task Area III: Performance and Lifetime Evaluation

The two Project Areas within this Task Area, *Environmental Test Methods* and *Noise Measurement Technology*, will have the following objectives: to develop, test and evaluate, and verify the concept of composite unit accelerated life tests (CUALT), other environmental test methods, the characterization of extraneous noise signals, the definition of required measurement methods, and the development, fabrication, and evaluation of T&E facilities, all to provide the capability of determining the lifetime operational characteristics of transducers.

Deliverables will be CUALT and extraneous noise test procedures and the accompanying test and evaluation facilities.

2.3.4 Task Area IV: Transducer Engineering Development

This Task Area is the link between the R&D and the transducer acquisition programs. This is the area in which the STRIP has been greatly strengthened and where the shift toward design specifications will culminate. The objectives will be: to implement the materials development, component development, engineering analysis, and the performance evaluation methods into the design and construction of fleet transducers, to proof the preliminary designs by performing CUALT, extraneous noise, and other T&E procedures, to provide feedback to other R&D phases, and to prepare final design specifications which will be used in the fleet transducer acquisitions.

Deliverables will be final and complete design specifications for the DT-605, TR-316, SQS-56( ), DT-276( ), spherical array, and SQS-53( ) transducers.

3. SPECIFIC TASKS

This section describes specific work units which will be performed in each of the major task areas. Each specific work unit description includes a statement of the objectives of the work unit, the approach to achieve these objectives, and a list of the specific milestones which are identifiable at this time.

3.1 WORK UNIT I.A.1 NOISE CRITERIA AND STANDARDS

Principal Investigator; NOSC-C. I. Bohman

3.1.1 Objectives

The objectives of this task are to identify and quantify Sonar System(s) parameters and acoustic radiation criteria which will define the threshold at which hydrostatically induced transducer noise constitutes a threat by detection or degraded system performance.

3.1.2 Approach

This task is twofold. First, a theoretical analysis of the problem needs to be conducted, in terms of the maximum far-field acoustic source level that can be emitted from the transducer before detection is possible, and the maximum near-field acoustic noise or electrical feedback that can be tolerated before the own ship's sonar capability is significantly degraded. The results of this analysis must include parameters that reflect realistic detection capabilities and operational requirements, and which also reflect specific sonar array configurations and requirements. Second, in order to verify that the parameters selected for the detection criterion and sonar interference standards are meaningful and reflect the real shipboard situation, it will be essential to obtain measurements taken at sea of near-field and far-field acoustic noise emissions from transducers. Measurements must also be made of the corresponding electrical self-noise generated in the offending transducer as well as other nearby acoustic sensors.

In order to accomplish the second part of the task, at-sea experiments will be planned during FY82, although they may not be carried out until FY83 due to funding restrictions in the current fiscal year. The experiments will be planned in cooperation with other STRIP principal investigators whose tasks share an interest in such data.

Two contracts which were initiated in FY81 will continue into FY82: Dr. D. Ross (Tetra Tech Services, Inc.) will continue his evaluation of work performed to date and Dr. D. Johnson (Rice University) will continue his investigation of coherent detection methods.

3.1.3 Milestones

Meeting with other principal investigators to define data requirements for at-sea experiments.	1st qtr.
Final report on detection of radiated acoustic noise by coherent detection methods.	3rd qtr.
Final report on the theoretical study of the effects of transducer extraneous noise on acoustical and electrical interference in sonar operation using the spherical array.	4th qtr.

3.2 WORK UNIT I.A.2 IDENTIFICATION OF NOISE CHARACTERISTICS

Principal Investigator: NWSC-T. J. Laughlin

3.2.1 Objectives

The objectives of this task are to gather initial data for the determination of emitted extraneous noise from submarine sonar transducers, hydrophones, and transducer materials and to characterize any such emissions for further analysis.

3.2.2 Approach

The compilation of the prioritized list of transducers, hydrophones, and transducer materials and the evaluation of listed items with respect to emitted extraneous noise will remain as continuations of work begun in FY81. The listed items will undergo cyclic changes in hydrostatic pressure at the Sonar Extraneous Noise Facility and will be instrumented with additional sensors and measurement equipment if emissions are detected. Any detected noise emissions will be analyzed and described by the techniques developed in FY81. Information obtained during analysis will be catalogued (in a standard format agreed upon in cooperation with other STRIP principal investigators) and stored on magnetic tape for future use.

In the past, completion of some STRIP tasks have been delayed because the existing noise facilities were unavailable due to production and first article test schedules. During FY82, separate pressure vessels will be installed for R&D use. One large vessel (2m in internal length x .68m in inside diameter) and two or three (depending upon availability) small vessels of the same type presently used in the Sonar Extraneous Noise Facility will be utilized. Although these R&D pressure vessels will share some operating equipment and instrumentation with the production test facility, they can be operated independently and will not interfere with ongoing production work.

3.2.3 Milestones

Continue compilation of prioritized list and evaluation of listed items.	1st-2nd qtrs.
Establish standardized format for cataloguing noise analysis data.	2nd qtr.
R&D pressure vessels on line, continue testing of items from prioritized list.	3rd qtr.
Report on evaluation of tested items on prioritized list.	4th qtr.

3.3 WORK UNIT I.A.3 NOISE DATA ANALYSIS AND ACQUISITION

Principal Investigator: DTNSRDC-J. F. O'Donnell

3.3.1 Objectives

The objectives of this task are: (1) to conduct a review and analysis of at-sea data available at DTNSRDC, and (2) the identification of subsequent data acquisiton and analysis needs, the determination of optimum measurement methods and data format, the design of at-sea experiments, and the collection of at-sea data during scheduled full-scale acoustic trials.

3.3.2 Approach

The amount and scope of available data will first be determined, and thoroughly reviewed to locate occurrences of transducer extraneous noise. The data review will include both radiated noise data and self-noise data and will be processed to determine signal parameters characteristic of the phenomenon, such as duration, spectral energy content, repetition rate, sound pressure level, etc.

Based upon the results of the review of existing data, additional data requirements will be identified and methods for additional data acquisition will be defined and proposed. This may include the design of specific experiments to acquire transducer extraneous noise data, as well as the determination of methods to gather the data concurrently with DTNSRDC standard submarine acoustic trials and special systems trials. Any at-sea experiments and data formatting will be planned in cooperation with other STRIP principal investigators whose tasks share an interest in such data.

3.3.3 Milestones

Complete review of existing DTNSRDC data.	1st qtr.
Complete definition of additional at-sea experiments.	2nd qtr.
Complete analysis of available data.	3rd qtr.
Report documenting the review and analysis of existing data as well as recommendations for additional data requirements and measurement methods.	4th qtr.

3.4 WORK UNIT I,A.4 LIFETIME RELIABILITY DEFINITIONS

Principal Investigator: TRI-Dr. R. L. Smith

3.4.1 Objective

The objective is to apply reliability modeling methodology to the improved versions of the DT-276 transducer being developed at NWSC and the improved SQS-56 transducer being developed at NOSC to determine probable life expectancy and to detect weak points in the design.

3.4.2 Approach

Reliability modeling and lifetime prediction for transducers has always borrowed heavily from the highly visible and firmly entrenched methods of MIL-HDBK-217C. The appeal of the handbook approach, which employs the exponential reliability model is in its simplicity and apparent determinism although it is fully developed only for electronic devices. However, exponential modeling is not appropriate at the component level in situations where gradual physical changes of condition occur. A number of reliability models have been advanced and the first step in this investigation will be to identify modeling techniques that best lend themselves to characterizing the reliability and service lives of sonar transducers. However, this will be a limited effort which will build principally on previous work and is expected to lead to a modeling format consisting of both Bayesian and classical methods. The main effort will be to apply modeling methods specifically to the improved versions of the DT-276 and SQS-56 transducers being designed and developed at NWSC and NOSC. The principal investigator of this work unit will function as the reliability modeling and control agent in the Government design development effort. An important by-product of this work will be the explicit identification of what modeling parameters are important and in need of detailed determination of correct values.

3.4.3 FY82 Milestones

Determine best modeling approach.	2nd qtr.
Present and defend DT276( ) reliability prediction.	3rd qtr.
Present and defend SQS-56( ) reliability prediction.	4th qtr.

3.5 WORK UNIT I.B.1 FAILURE MODES FROM WATER AND CUALT ANALYSIS

Principal Investigator: TRI-D. D. Barrett

3.5.1 Objectives

The objectives are to determine the effects of water or water vapor on the performance and lifetime of transducers and the aging mechanisms that accelerated life testing induces in transducers.

3.5.2 Approach

This work unit will consist of two phases. The first phase continues from FY81 and is designed to determine what happens to water once it gets into a transducer and how it affects the lifetime of the transducer. Specially instrumented DT-308's which have been extensively modified are used as test prototypes to answer the following questions:

a. Are desiccants necessary or effective for every type of transducer and, if so, where are they best located?

b. When the internal humidity of the transducer element increases, what is the effect on the resistance of various components?

c. What is the effect of internal moisture on the mechanical properties, such as viscosity, pH, sound speed, etc., of the fill fluids?

d. At what rate does moisture permeate into a potted transducer and what are the effects?

e. How do all the effects interact to affect element operation?

The second phase will be an "autopsy" of the TR-316 and DT-605 transducers that have been exposed to the accelerated life testing in the CUALT tasks at NOSC in FY80 and FY81. These transducers will have gone through an initial test-fix-test cycle followed by accelerated testing to simulate 7 years real life. The autopsy will investigate wearout modes to assist in determining failure mode parameters. The final output of this will be a lifetime prediction for the TR-316 and DT-605.

3.5.3 FY82 Milestones

Start autopsy of CUALT DT-605.	2nd qtr.
Complete the first phase with a final report.	3rd qtr.
Start autopsy of CUALT TR-316.	3rd qtr.
Lifetime predictions report.	4th qtr.

3.6 WORK UNIT II.A.1 TRANSDUCER ELASTOMERS

Principal Investigator: NRL/USRD-Dr. C. M. Thompson

3.6.1 Objective

The objective of this task is to establish specifications to enable the Navy Sonar community to acquire optimized, reproducible elastomers.

3.6.2 Approach

A major concern for fleet transducer reliability is in the area of elastomers. Many reasons contribute to their failure, including (1) the severe stresses imposed by environment, (2) designer's choice of a proprietary, nonoptimized formulation and (3) the lack of meaningful quality control in the procurement cycle. At NRL/USRD, instrumental techniques have been developed for the compositional analysis of a neoprene rubber, Neoprene 5109. By using techniques including HPLC and GPC, chemical composition analysis and physical property evaluation are near completion. Sample-buys will now be carried out from a number of commerical sources to demonstrate its manufacturability. Batches of 5109 samples will be tested for aging properties, electrical resistivity, water permeability, and bondability. When these test results are available, they will be combined with comments received from the first draft of 5109 specification. A final design specification for Neoprene 5109 will then be prepared and published.

Measurements of the water permeability of a variety of currently used transducer elastomers will be performed as a function of temperature. In addition, experiments will also be carried out for these elastomers to determine (1) compatibility with fluids, (2) bondability to ceramics and metals, (3) high voltage breakdown and aging characteristics. These data will form additional input to the data base for transducer materials being developed at NRL/USRD. They will also be used in support of trouble-shooting on existing systems and design recommendations for upcoming new procurements of DT-276 and SQS-56 transducers. Measurements on these elastomers will also be made to determine their dynamic moduli over a wide range of temperature and pressure. An acoustic impedance tube and an automated Nolle string apparatus will be employed to obtain the sound speed, dynamic modulus and acoustic attenuation. The complete data will be used for the development of correlations with the chemical composition of transducer elastomers.

3.6.3 FY82 Milestones

Complete Neoprene 5109 "sample-buys" and WVTR modification and temperature calibration.	1st qtr.
Complete elastomer-fluid compatibility study and report results.	3rd qtr.
Complete elastomer-ceramic and elastomer-adhesive evaluation and submit report and input for DT-276 and SQS-56 transducer designs.	3rd qtr.
Complete Neoprene 5109 design specifications.	4th qtr.

3.7 WORK UNIT II.A.2 TRANSDUCER CERAMICS

Principal Investigator: NRL-A. C. Tims

3.7.1 Objective

The objective is to investigate the effects of filament winding on piezoelectric ceramics in transducer configurations with a final goal of establishing a basic specification for fiber-wrapped ceramics.

3.7.2 Approach

The approach in FY81 has been to accept the ceramics as they are and to delineate the variables in the wrap process to reduce them to the lowest possible terms. The approach will continue in FY82 with the following steps:

a. Determine methods to precisely control the winding tension from transducer element to transducer element.

b. Obtain equipment to develop an in-house fiber-wrap capability at the NRL-USRD to give control over all phases of the prestress process and techniques.

c. Fiber-wrap K ... as currently used in the new TR317/318 sonar transducer ... the effects of process variations on the stress ... the use of strain gauges strategically positioned on ...

d. Measure the el... parameters on all rings before prestressing and after to ... ations which may arise due to process variations.

e. Work with NOSC ... -56 buy to get typed data included in a Contract Data ... ments List (CDRL). Interface with NUSC on TR-317/318 ... obtain typed data in a CDRL.

f. Correlate var... electrical parameters with variations in prestress magn... ain available CDRL data and compile for data base. Do... measurements with data variations.

3.7.3 FY82 Milestones

Obtain prestress equipment and evaluate methods for tension control using strain gauges on cylinders.	1st qtr.
Measure electrical parameters before and after prestressing and determine variations. Determine prestress magnitude ... by use of strain gauges. Add data from CDRL requirements to data base.	2nd, 3rd qtr.
Continue to evaluate prestressed rings and correlate data. Document results in a formal report. Evaluate the results of the investigation to determine future direction of the program. Provide fiber-wrap assembly procedure for TR317/318 to NUSC.	4th qtr.

3.8 WORK UNIT II.A.3 ALTERNATIVE MATERIALS

Principal Investigators: NWSC-K. Niemiller and NRL/USRD-Dr. C.M. Thompson

3.8.1 Objective

The objectives include two different phases:

- The evaluation of the ability of plastics to withstand an ocean environment.
- The development of a nonproprietary acoustic polyurethane material for transducer encapsulation, which meets the specified physical, mechanical, electrical and acoustic properties satisfying fleet requirements.

3.8.2 Approach

The approach to the first objective has been to perform a two-year equivalent accelerated life test (ALT) on eight types of glass-filled thermoplastics. Parallel to this, the same materials are exposed to an ocean environment for two years. Water absorption, volume change, tensile and shear strength, and sound speed will be measured on each of the materials. Conditioning and testing for the ALT portion of the program was completed in FY81. The ocean environment portion of the program, being a real time comparison, will be completed in FY82. Material samples exposed to an ocean environment for one year will be withdrawn and tested in November 1981.

Encapsulants have long presented failures from a variety of causes, most commonly related to the long-term oil or seawater exposure between temperature extremes. Polyurethanes cured with 4,4'-methylene bis(2-chloroaniline), or MOCA, have been used as encapsulants with reasonable success. Unfortunately, MOCA is a carcinogen and presents a serious health hazard in handling. A MOCA-free nonproprietary compound will be developed, aiming at the use of chain-extenders such as the deactivated aromatic amine, diaminotoluene and 4.4'-methylene bis(2-methylaniline). A material development contract initiated in FY81 has begun the work in this area, and various testings will be carried out at NRL to provide feedback for synthesis modification.

3.8.3 FY82 Milestones

Perform the testing of one-year ocean environmental samples, and prepare report.	1st qtr.
Complete the polyurethane development, propose the final formulation, and complete evaluation of the samples.	3rd qtr.
Complete the evaluation of additional ocean environmental samples and prepare final report.	4th qtr.

3.9 WORK UNIT II.B.1 UNSHIELDED CABLES

Principal Investigator: Ga. Tech. Research Inst.-H. Denny

3.9.1 Objective

The objective is to determine the extent to which the use of unshielded cable in place of shielded cable will affect the electrical performance and reliability of sonar systems.

3.9.2 Approach

This investigation was initiated in FY79 with a study of the mechanical strength of unshielded cables. In FY81, the present effort was started to consider from an electronics viewpoint the use of unshielded vs. shielded cable on the outboard side of a submarine. The FY82 effort will be the second, and final, increment of this investigation.

The first step has been to survey and analyze the installation of the DT-276 hydrophone of the BQR-7 and BQQ-5 systems on submarines to determine the electromagnetic interference (EMI) environment and the present practices of utilizing shielding on cables. Other sonar systems have also been included in the survey to the extent of defining EMI limits, shielding practices, and impedance limits of the hydrophones and signal amplifiers.

The second step has been to develop the theoretical modeling of shielded vs. unshielded cables necessary and sufficient to predict the electrical performance and reliability of individual and arrays of DT-276 hydrophones in the EMI environment found exterior to the hull of a submarine. The theoretical models and predictions are being generalized beyond the present DT-276 practice to provide for a range of sensor and amplifier impedances and for balanced and unbalanced amplifier inputs. The theoretical modeling uses as a starting point the methods of Dr. Clayton R. Paul as reported in the series of eight volumes of Rome Air Development Center Technical Report 76-101, and is extended to the sea water environment.

The FY82 task shall be to devise and implement experimental procedures to verify the predictions obtained from the theoretical modeling concerning the electrical performance and reliability of hydrophones in the EMI environment exterior to the hull of a submarine. The frequency range of interest is 100 to 20,000 Hz.

3.9.3 FY82 Milestones

Final report and recommendation on the use of unshielded cables.	3rd qtr.

3.10 WORK UNIT II.B.2 CABLE SPLICES

Principal Investigator: TRI-D. E. Glowe

3.10.1 Objective

The objectives are to identify DSS-3 cable splices used or proposed for use in the fleet, select three preferred splices representing cast, molded, and mechanical systems, test these three systems under accelerated life test, and determine the reliability and life expectancy of the splices.

3.10.2 Approach

Splicing of underwater cable is required for some sonar applications. When a splice is necessary it is generally constructed by fleet personnel under adverse conditions. It is essential that the constructed splice perform electrically and mechanically as well as the original unspliced cable and do so for the life expectancy of the attached hardware, which can range up to 15 years. Two splice systems are now used in the fleet; a cast epoxy splice using a kit manufactured by the 3M Company and a vulcanized neoprene splice developed by NUSC/NL. Mised results using these splices have been reported from the fleet. Several new splice systems are being proposed by various organizations for underwater use. Life and performance data have been lacking from fleet-applied splices. Of the proposed new systems, only manufacturer's data are available, and these data do not represent submarine service conditions. Data are sketchy for existing splices, however, splice failures reported from the fleet indicate that failure modes are related to shorting of spliced conductors, flooding of the splices due to loss of bond between the splice/cable interface, and degradation of the splice insulation resistance below specification.

While it is true that effective splices can be made in the laboratory, it is equally true that all splices are not equally good because of varying quality control. The approach here will be to quantify the reliability and lifetime of splices by empirical test and evaluation. The complete work unit is expected to take approximately 18 months, of which this the first increment. An input on the reliability of splices will be provided to the preparation of the critical item product fabrication specification for the DT-276( ).

3.10.3 FY82 Milestones

Identify and design splices.	1st qtr.
Input on cable splices to DT 276( ).	2nd qtr.
Perform screening tests.	2nd qtr.
Evaluate results and prepare long term splice systems.	3rd qtr.
Begin the ALT of best splice systems.	4th qtr.

3.11 WORK UNIT II.B.3 CORONA CONTROL

Principal Investigator: NRL-L. P. Browder

3.11.1 Objectives

The objectives are to identify the causes and cures for corona and high voltage breakdown in sonar transducers. The FY82 task will include:

- an investigation of the corona inception voltage (CIV) level on the internal interconnection assembly of transducers, which includes individual studies of the applicable material and electrode configurations involving the wiring, wire insulation, foil electrodes, and foil solder tab coatings.

- providing recommendations, as required, of voltage test levels involving CIV and voltage breakdown for specific transducer configurations so that the result will be electrically reliable operation.

- preparing a handbook that will include the appropriate information from the corona task studies that can be used to prepare transducer procurement specifications for corona and voltage breakdown requirements.

3.11.2 Approach

This investigation is designed to locate and quantify the electrode geometry in sonar transducers that causes the assembly to form corona. The internal interconnecting system will be logically subdivided into separate parts, and models of these parts will be constructed. These models will be tested in a Biddle corona tester to establish the corona inception voltage. As appropriate, the electrode dimension, shape, and separation distance will be changed to quantify the effect of changing the parameters. The different wiring insulation materials will be evaluated on a comparative numerical basis to determine if there is a preferred kind used in sonar transducers. The study of electrode foil coatings will be made with electrode shapes that yield comparative data. The results will be made available to specification writers and transducer designers. Specific transducer designs will be analyzed for electrical reliability using mathematical formulas developed for this purpose.

3.11.3 Milestones

Study corona inception voltage effects on various hook-up wire configurations and evaluate wiring insulation materials for transducer use.	1st qtr.
Study corona forming mechanisms associated with foil electrode and solder joint geometry.	2nd qtr.
Examine the use of coating materials to reduce corona on foil electrodes and write report. Provide input to spec. development of SQS-56 transducers.	3rd qtr.
Prepare handbook on corona and voltage breakdown specification guidelines for transducers.	4th qtr.

3.12 WORK UNIT II.B.4 CERAMIC STACK JOINTS

Principal Investigator: NOSC-J. Lockwood

3.12.1 Objectives

The objectives are to identify and quantify the temperature dependent parameters of cement/electrode joints as used in transducer fabrications, to develop optimum cement joint configurations and fabrication techniques through math modeling and experimental verification, and to apply the results to improved resonator designs.

3.12.2 Approach

Development of techniques to independently measure ceramic parameters and cement/electrode joint parameters was part of the FY81 objective for the STRIP cement joint investigation. With those techniques, ceramic and cement/electrode joint parameters will be measured as a function of temperature. The results can be incorporated into an existing computer model (also a result of FY81) of a ceramic stack resonator which contains cement joints, in order to give the model temperature dependence.

Obtaining temperature profiles of a dumiloaded resonator under high drive was a FY81 objective. Guided by those results we will apply the proper temperature dependent values for the ceramic and cement/electrode joint parameters to the computer model of the ceramic stack resonator, in order to simulate its operational performance.

The final modeling results will allow us to determine the role of the cement/electrode joint in the performance degradation of stacked ceramic resonators in heated environments. These results will be applied to investigate possible improvements of stacked ceramic resonators. In addition, we will be able to assess the applicability of recent corrective actions taken for stacked ceramic resonators (with stress rods), to various other types of piezoelectric resonators which contain ceramic sections that are cemented together. For example: some resonators employ stress rods, others do not; some resonators are longitudinally stacked while others contain ceramic sections that are cemented together in a ring fashion.

3.12.3 FY82 Milestones

Measure ceramic parameters vs. temperature.	1st qtr.
Measure cement/electrode joint parameters vs. temperature.	2nd qtr.
Apply modeling predictive capability.	3rd qtr.
Develop improved resonator designs and assembly techniques. Provide firm design input to the TR-316 and SQS-56 product fabrication specification.	4th qtr.

3.13 WORK UNIT II.B.5 ACOUSTIC EMISSION APPLICATIONS

Principal Investigator: NUSC-T. J. Mapes

3.13.1 Objectives

The objective of this work unit is to determine the feasibility of applying acoustic emission techniques to the problem of localizing noise mechanisms in transducers.

3.13.2 Approach

Acoustic emission gained rapid acceptance as a nondestructive test method for locating flaws in pressure vessels, aircraft components, mines, welded joints, and reinforced plastic structures. To apply this method, an empirical or analytical model of sound paths in the structure is required. High-frequency sensors are then applied to the structure in specified critical locations and the structure is mechanically loaded. Stress waves emitted by the structure are detected by the sensors and the wave characteristics are then used to estimate the source of the acoustical emission. However, application of this technique to underwater electroacoustic transducers poses several problems. Cecause of the size and complexity of a typical transducer, the sound paths throguh the structure are difficult to define and the acoustic emission sensors required (very broad bandwidth and a short "ring down" time), for the most part, do not exist.

In a longitudinal vibrator type of transducer (TR-155, TR-317, TR-318), this effort will attempt to adapt a ten channel acoustic emission test system to the problem of noise source localization. Sectioned, or cut-away, transducers will be instrumented and simulated acoustic emissions used to determine the various propagation paths. Fully assembled transducers will be instrumented and subjected to both uniaxial stress in air and stress due to hydrostatic pressure. Where the required acoustic emission sensors and sources are unavailable commercially, they will be developed "in-house" (this has already been done to some extent). Defined acoustic emission paths and the specialized instruments will be used to develop the noise location algorithms.

The end product of this effort will not only be a technique for application to identified problems, but also a Quality Control Procedure which would permit detection of noisy transducer elements during manufacture.

3.13.3 Milestones

Complete procurement/development of underwater acoustic emission sensors.	3rd qtr.
Interim definition of acoustic emission paths in a longitudinal vibrator; interim report on the applicability of acoustic emission techniques.	4th qtr.

3.14 WORK UNIT II.C.1 ENGINEERING ANAYLSIS

Principal Investigator: NRL-Dr. R. W. Timme

3.14.1 Objectives

To develop and utilize mathematical models to predict transducer behavior, to make quantitative comparisons between predictions and evaluation results, to understand and resolve unexpected results, to provide guidance to R&D in materials, components, and noise, to provide contingency capability for future problem areas, and to provide engineering documentation interfacing the transducer procurements and systems applications with the R&D efforts.

3.14.2 Approach

The use of mathematical models for the prediction of performance of transducers and transducer components will be investigated. Many work units of STRIP aim at improving components such as ceramics, fluids, rubbers, etc. The effects of such improvements on transducers' performance need explicit evaluation. The initial approach in FY81 was to investigate the effect of the variation in ceramic properties on transducer performance using the TAC program and known production data on the ceramic. The effort in FY82 will be to evaluate changes in other materials on transducer performance to determine the impact of "tight" vs. "loose" specifications.

Each of the other work units in the program will be fully documented as an essential part of that particular effort. This work unit will provide an overview and will link the various work units together. The aim is to help avoid the continued "reinvention-of-the wheel" and to ensure that the failures as well as the successes will be discussed. All too often in the past, developments and redesigns that have resulted in successful hardware have not been documented in terms of why certain materials and/or construction details are chosen over others. Later, the same decisions must be remade. Based on the results of this program, consideration will be given to procurement via construction specifications rather than performance specifications. The approach here will be to determine and document the proper RDT&E of transducers and hydrophones as required for future acquisition. All fleet sonar systems will be screened to provide a base from which to determine the required or necessary R&D. This determination will depend upon complexity of design, unit cost, repairability, procurement quantities and replacement periodicity.

3.14.3 Milestones

Progress report on entire program.	1st qtr.
Report on ceramic variations and transducer performance.	1st qtr.
Progress report on entire program. Annual Program Review.	2nd qtr.
Progress report on entire program.	3rd qtr.
Progress report on entire program.	4th qtr.

3.15 WORK UNIT III.A.1 COMPOSITE UNIT ACCELERATED LIFE TESTING

Principal Investigator: NOSC-J. Wong

3.15.1 Objectives

The primary objective is to develop and experimentally validate detailed procedures for planning and conducting a CUALT on a specific sonar transducer, in such a way as to develop realistic conclusions and recommendations for improving the reliability of the transducer. A secondary objective is to aid directly in the development of selected transducers by identifying inherent design flaws that can be avoided or modified to provide improved reliability and longer life.

3.15.2 Approach

Emphasis on transducer composite unit accelerated life testing (CUALT) as opposed to piece-part testing, for example, resulted partly from conviction that it is not reasonable to anticipate many ways problems can result from interactions in composite production transducer units. Design and quality-control deficiencies combine in complex fashion with fleet operationally-induced physical and chemical interactions of piece parts. Only composite-unit stress exposure is likely to reveal resulting problems prior to fleet operations. Piece-part testing in general has proven most useful after problems have been encountered in composite transducer units under normal operating conditions. The approach will be to develop test procedures for a CUALT which will simulate conditions, on a composite transducer, approaching those encountered in fleet use of hardware to provide a realistic assessment of realibility of hardware prior to fleet use. Any failures will be investigated on a piece-part basis to determine details of failure mechanism and provide guidance for design change recommendations to correct failure problems. For FY82, the results from CUALT of at least two transducer designs will be considered: the TR-316 and the DT-605. NOSC will coordinate the efforts of Work Unit I.B.1 in the final analysis of the transducers having experienced the equivalent of 7 years life use. Emphasis will be placed upon finding cost effective ways to implement the CUALT plan and in defining the final CUALT procedure for under-ice-type transducers. The final report will be a lifetime prediction for TR-316 and DT-605 transducers.

3.15.3 FY82 Milestones

Complete the 7-equivalent years CUALT on the DT605's. Coordinate the "autopsy" of the aged DT-605's.	2nd qtr.
Complete the 7-equivalent years CUALT on the TR-316's and coordinate the "autopsy". Final report on lifetime predictions for TR-316 and DT-605 transducers.	4th qtr.

3.16 WORK UNIT III.B.1 MEASUREMENT METHODOLOGY

Principal Investigator: NRL-Dr. A. L. Van Buren

3.16.1 Objective

The objective of this task is to investigate procedures for determining, from measurements made in small pressure enclosures, the free-field signals produced by sonar components when they undergo changes in hydrostatic pressure.

3.16.2 Approach

There are four basic approaches to obtaining free-field signals in a small tank. These are, in order of increasing technical complexity:

(1) By submerging an acoustically transparent pressure vessel in a larger body of water. The use of small vessels could cause a logistics problem because of the large number of transducers required for production test and evaluation. A variation of this approach, however, could be used to evaluate a large number simultaneously, e.g a section of a spherical array of transducers. This approach provides a measurement condition that not only evaluates a large number of transducers simultaneously, but also evaluates them under simulated array conditions. Glass fiber/epoxy composites, as are commonly used in commercially available pressure vessels, may emit extraneous noise as a function of hydrostatic pressure; therefore, different composites will be investigated for use as a transparent dome material.

(2) Through the use of anechoic linings for the tank walls to reduce the size of the pressure tank required to test a single sonar component. Alternatively, the open tank of water required in approach 1 could be lined to reduce its size.

(3) The use of signal extrapolation methods might allow the entire free-field signal to be recovered from the early part of the received signal that is uncontaminated by reverberations from the tank walls.

(4) Complex transfer functions might be used to relate reverberation-contaminated signals measured in the tank to free-field signals.

During FY82, the primary effort will be on the first two approaches. The purpose of this effort will be to determine a feasible measurement procedure, not to develop a system based on such a procedure.

3.16.3 Milestones

Completion of report on the results of transparent pressure vessel approach.	3rd qtr.
Completion of report on the results of the anechoic tank lining approach.	4th qtr.

3.17 WORK UNIT III.B.2 EXPERIMENTAL MEASUREMENT CORRELATION

Principal Investigator: NOSC-C.I. Bohman

3.17.1 Objectives

To develop methods and techniques to relate the transducer self-noise as recorded in small pressure tanks to an equivalent characterization of that noise in an operational configuration, and to relate the noise characterization to the transducer self-noise criteria.

3.17.2 Approach

This task will combine elements from the Measurement Methodology area begun in previous years with an experimental approach to the correlation between operational configurations and T&E measurement conditions.

To measure transducer self-noise in pressure tanks while changing pressure, it is necessary to discern whether noise that is detected originated in the transducer or in some part of the pressurization system. Previous work has provided the capability to analyze transducer noise as recorded in pressure tanks and to develop a technique for discriminating transducer noise from noise originating elsewhere. That work will be completed in FY82 with the development of an initial hardware/software design to implement the results. Recordings of transducer self-noise obtained during FY81 will be analyzed for the comparison of the peak voltage thresholding technique presently used in T&E measurements with the radiated energy criteria early in FY82.

To successfully apply the criteria developed under STRIP task I.A.1 to the measurement of transducer self-noise in pressure tanks, it will be necessary to investigate the differences between tank measurements and operation configuration measurements and to apply some conversion factor to relate one to the other. During FY80 and FY81, the problems of trying to make calibrated acoustic measurements in the same type of pressure tank as that used at NWSC were investigated. The approach will be to extend the results of the previous effort to establish reasonable bounds or limits to the transducer self-noise as presently measured and to convert those bounds by means of a transfer function or conversion factor to corresponding bounds or limits in the free-field and actual operational configurations. A one to one correspondence in amplitude, frequency, and time would be difficult, if not impossible, to achieve in developing a transfer function relating tank measurements, free-field, and operational configurations because of the variability of conditions that exist under the different measurements. Therefore, it is more reasonable to approach the problem with the idea in mind of measuring average values, with a corresponding distribution around those average values, and setting bounds for transfer self-noise that would be established by comparing transducer noise in a tank, free field, and operational configurations.

With TR-155 transducers (including the one modified by NRL), experiments will be set-up to excite each transducer with a high power, impulse type signal and to make measurements of the radiated and electrical response both in the small reverberant pressure vessels and open water. Comparisons will be made of each type of measurement in order to develop the limits needed to relate both situations to each other. After the appropriate limits and transfer functions have been established, the results will be related to the criteria developed in Task I.A.1.

3.17.3 Milestones

Report on the investigation to remove extraneous noise from tank measurements and the design of the initial hardware/software system to implement the results.	2nd qtr.
Report on the results of the comparison of the peak voltage thresholding technique presently used in T&E measurements with the radiated energy criteria being developed.	2nd qtr.
Compare the results of the TR-155 radiated acoustic and electrical impulse responses measured in both a small tank and the free-field and establish bounds in terms of amplitude, frequency, energy, and time duration that will describe a transfer function.	3rd qtr.
Analyze and compare the results of at-sea experiments with the results of the tank and free-field measurements. Using the results, develop a transfer function to relate pressure tank measurements with the criteria developed in Task I.A.1.	FY83

3.18 WORK UNIT III.B.3 MEASUREMENT CORRELATION MODELS

Principal Investigator: Bolt, Beranek and Newman, Inc.-Dr. N. C. Martin

3.18.1 Objective

The objective of this work unit is to correlate transducer extraneous noise measurements made in small reverberant tanks with the boundary conditions of the transducer in the operational configuration through the use of analytical models.

3.18.2 Approach

The test conditions in a small reverberant pressure vessel are so different from those seen by the transducer under operational conditions that significant questions exist about the applicability of current data to the examination of the operational impact of measured transducer self-noise. Although the procedures established by this task will be generally applicable to various transducer and/or test chamber configurations, the scope of this initial effort will be limited by focusing on the TR-155 transducer. The approach will consist of developing models of the transducer/test chamber configuration and of the transducer in its operating configuration and then applying the same transducer noise mechanism to each model. The analysis of the test chamber/transducer configuration will consider the dynamics of the transducer, the fluid space inside the chamber, and the dynamics of the chamber itself. The selection of modeling techniques will be guided by an examination of existing TR-155 transducer models and any available structural or acoustical response data for the test chamber. The analysis of the "in-situ" self-noise radiation will consider the radiation from a single transducer noise transient when positioned in the spherical array. This analysis will model the array as a sphere with an appropriate impedance boundary condition (frequency dependent) determined from the characteristics of the transducer. The radiation problem will be that of a piston in a finite impedance sphere. Several potential transducer noise mechanisms will be examined and characterized either as providing a constant force or displacement input to some component of the transducer. These same input descriptions will then be used for both models and the results used to predict the relationship between far-field radiated noise and pressure vessel measurements for the chamber/transducer system under consideration.

A simple diagnostic experiment designed to verify the analytical model of the test chamber/transducer system will be conducted. A small acoustic source will be used to introduce a known volume velocity into the fluid space inside the chamber. Measurements of chamber pressure, test transducer output, head mass acceleration and chamber acceleration will be made and used to verify or refine various components of the analytical model.

3.18.3 Milestones

Completion of transducer/test chamber model.	2nd qtr.
Completion of model of transducer in the operational configuration.	3rd qtr.
Completion of diagnostic experiment, final report.	4th qtr.

3.19 WORK UNIT IV.A.1 TR-316 and DT-605 PRODUCT FABRICATION SPECIFICATION

Principal Investigator: NOSC-D. L. Carson

3.19.1 Objectives

The objectives are to theoretically characterize and experimentally validate design adjustment schemes (DAS's) for inclusion in the TR-316 and DT-605 Product Fabrication Specifications which will produce practical replica transducers on a production line basis.

3.19.2 Approach

The state-of-the-art is such that a stand-alone build-to-print specification is not likely to be successful. It is possible to include in a Critical Item Product Fabrication Specification precisely defined and bounded adjustments to be made by the contractor to accommodate the practical realities of component variations so as to meet the single unit performance requirements. The approach will be to determine precisely which components can be specified as build-to-print and how to do so, and which components require adjustment provisions and how to specify these adjustments in such a way that the contractor can reasonably be held responsible for unit performance while producing practical replicas of the existing proven transducer elements. In an iterative fashion, suitable predictive models for the TR-316 and DT-605 transducers will be developed which will link materials variability with single element performance and array performance. Alternate DAS's will be developed and verified in experimental transducers.

3.19.3 FY82 Milestones

Develop minimum complexity first iteration models for predicting the array performance for various DAS's for accommodating reasonable state-of-the-art parameter variations in production line quality TR-316 and DT-605 transducers. Determine the range of complex parameter variations which should be considered to accommodate reasonable production line quality PZT4 piezoelectric rings.	1st qtr.
Based on first iteration model predictions assess the usefulness of the various DAS's. Based on previous experience develop a preliminary plan for experimental evaluation of the various DAS's. Order long lead components and design and build the long lead experimental apparatus (such as DUMILOAD's, etc.)	2nd qtr.
Using experimental approach evaluate the DAS's for the TR-316 and DT-605's.	3rd qtr.
Based on interim experimental results and insight gained from first iteration model refince and apply predictive models as required. Prepare report that assesses the DAS's for the TR-316 and DT-605 transducers.	4th qtr.

3.20 WORK UNIT IV.B.1 SQS-56( ) PRODUCT FABRICATION SPECIFICATION

Principal Investigator: NOSC-D.L. Carson

3.20.1 Objectives

The objectives are to theoretically characterize and experimentally validate design adjustment schemes (DAS's) for inclusion in the SQS-56( ) Product Fabrication Specifications which will produce practical replica transducers on a production line basis.

3.20.2 Approach

The state-of-the-art is such that a stand-alone build-to-print specification is not likely to be successful. It is possible to include a Critical Item Product Fabrication Specification precisely defined and bounded adjustments to be made by the contractor to accommodate the practical realities of component variations so as to meet the single unit performance requirements. The approach will be to determine precisely which components can be specified as build-to-print and how to do so, and which components require adjustment provisions and how to specify these adjustments in such a way that the contractor can reasonably be held responsible for unit performance while producing practical replicas of the existing proven transducer elements. In an iterative fashion, suitable predictive models for the SQS-56( ) transducers will be developed which will link materials variability with single element performance and array performance. Alternate DAS's will be developed and verified in experimental transducers.

3.20.3 FY82 Milestones

Model a double mass loaded stack to test reproducibility of stack parameters with various ring parameters. Use SEADUCER as a check and determine parameters of importance.	1st qtr.
Based on first iteration model, assess the usefulness of the various DAS's. Design prelim experiments including dumbell loading and in-water testing. Order long-lead components.	2nd qtr.
Based on interim experimental results and insight gained from first models, refine and apply predictive models as required. Prepare report that assesses the DAS's for the SQS-56( ).	4th qtr.

3.21 WORK UNIT IV.C.1 DT-276( ) PRODUCT FABRICATION SPECIFICATION

Principal Investigator: NWSC-J. A. Parkes

3.21.1 Objectives

The objective is to develop a more reliable hydrophone for use in sonar systems such as the BQQ-5 and BQR-7.

3.21.2 Approach

The approach will start with the results of the FY81 task to develop improved hydrophone requirements. In FY81, an engineering anaylsis of the requirements of the BQQ-5 and BQR-7 system from the view of the transducer detection requirement was conducted. These results combined with the results of a comparison of the CUALT on DT-276 hydrophones with a failure analysis of those returned from the fleet will be used to develop a set of design requirements for an improved hydrophone. These requirements will lead to different design approaches such as integral versus in-board preamps, balanced versus unbalanced preamps, quick connect/disconnect versus a fixed cable, butyl versus neoprene boots, a butyl, unshielded cable versus the present DSS-3 cable and other considerations such as improved back-baffling and even direct substitution of the DT-513 with modified mounting. This information will be analyzed in FY82 and closely coordinated with BQR-7, BQQ-5, and SUBACS system managers. This will lead to the development of a preliminary set of drawings and design specifications with a reliability estimate and quality control plan. Communication and coordination will be established and maintained with Work Units I.A.4 (DT-276( ) Reliability Prediction), II.A.1 (Transducer Elastomers), and II.B.1 (Unshielded Cables). Those Work Units are specifically tasked to support this DT-276 Product Fabrication Specification development. A formal design review will be conducted on the preliminary design just as is done by the Navy on a contractor. After the design review, construction of 30 prototype DT-276( )'s will be initiated as a "sample buy". Information in the form of the latest design improvements will be provided to SEA63X5-1 for inclusion in current DT-276 procurements.

3.21.3 FY82 Milestones

Define physical and performance requirements.	1st qtr.
Obtain input from supporting work units and develop preliminary design and drawings.	2nd qtr.
Develop reliability prediction, quality control plan, and production procedures. Formal design review.	3rd qtr.
Complete preliminary design and start prototype construction.	4th qtr.

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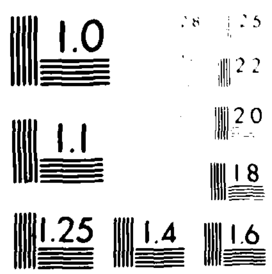

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